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Children and computers:
The development of graphical user interfaces to improve the quality of interaction

**A thesis submitted to Middlesex University
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THESIS CONTAINS DVD AND LEAFLET

Abstract

Children and computers:

The development of graphical user interfaces to improve the quality of interaction

The development of educational multimedia since 1994 has been characterised by a rapid expansion of new technologies. In the context of an exciting and controversial exploration of techniques, research into how children used computers in the classroom had been limited. The thesis therefore included a wide-ranging study into factors informing a deeper understanding of the way 5 to7-year-old school children use interactive computer programs. The thesis originated in contextual studies undertaken by the researcher in classrooms. The contextual research raised issues that are not the common ground of educational multimedia practitioners. These issues were explored in depth in the literature review. The thesis tested the potential improvements in interface design – an interactive educational CD-ROM using audio and visual resources from a BBC School Radio music series. The focus was not the music content or the teaching of the subject. The results of testing the research tool that used observation of groups of three children, interviews with individual children and teachers were summarised and improvements identified. The aim was to seek answers to the question 'How can the quality of computer interface interaction be improved?' Improvements were considered by enhancing the quality of interaction through greater depth of engagement by using the computer mouse to move icons on the computer screen.

In the process of contextual research the following issues were raised: the need for teachers to have a method of mediating the content of educational CD-ROMs, the physiological demands made on children in terms of eye search; the difficulties they encountered using navigation metaphors; and the potential of pseudo 3-D perspective interfaces. The research re-evaluates the relationship between children and computers in the familiar context of groups of three children using computers in the primary classroom, and resulted in a coherent set of suggestions for a more effective holistic paradigm for the design of multimedia programs that takes into account practical realities in classroom environments.

Acknowledgements

I owe a great debt of thanks to a large number of people who have assisted in the study in different ways. Terry Russell, Senior Lecturer in IT at Middlesex University suggested the idea in the first place: Professor Richard Andrews, Research Professor in Education, Middlesex University, and later Professor Trevor Corner who succeeded him: also Stephen Boyd Davis, Principal Lecturer, Lansdown Centre for Electronic Arts at Middlesex, provided invaluable experience in their various fields as the supervisory team. Terry Marsh, Head of BBC Education (1993-1996) gave the researcher the opportunity and supported the Starcatcher project that began this journey of discovery. Staff at the Open University Multimedia Production Centre include David Williams who provided encouragement and support. Magnus Moar and Gordon Davies from the Lansdown Centre for Electronic Arts and also Diana Freeman from the Advisory Centre: Computers in Education all gave their unstinting professional advice. Mike Saunders carried out the programming. The research would not have been possible without the schools, teachers and children who allowed the researcher to visit and talk to them for the survey. The late Denis Kemp is especially remembered as the inspiration for my career in education and photography. Caroline Dudley's professional proof reading and my parents who offered lay advice. Finally the support and encouragement of my wife Elizabeth and our children Becky and Sam who have come to believe their Dad and his computer are one and the same being!

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Chapter 1: From analogue to digital: a new interface for education

1.1 Introduction

The researcher, as an education radio producer for the British Broadcasting Corporation began the thesis at a time when the organisation was responding to developments in computers and educational CD-ROM technology. In 1994, the researcher was asked to report on the CD-ROMs in Primary School Initiative (National Council for Educational Technology). The researcher then proposed a trial multimedia project using the BBC's own radio resources and the Head of BBC Education commissioned the project. Staff at the School of Lifelong Learning and Education at Middlesex University were approached for advice on the scope of the project. It was suggested that the contextual research of CD-ROMs in the Primary School Initiative and the BBC's trial multimedia research project should be formalised as a PhD. The researcher has pursued the process from 1995 to 2002.

The context of the thesis is the growth in use of information technology in schools, particularly in the area of multimedia resources for learning. In this period of growth the parameters of what constitutes educational value are changing as new forms of interactivity and technology develop. An analysis of their educational value in a classroom environment is therefore much needed. The thesis identifies the gaps in the research during a period of very rapid growth in the new technology and defines principles that will inform professional future producers of interactive computers and teachers using new media technologies in the classroom. The thesis is a critical reflection on developments in multimedia software by a researcher with a background in radio and audio-visual education. The perspective provided by the researcher's experience has led to a wider review than the traditional literature in the field. The thesis collects evidence from the wider review to identify themes and patterns for improvement in interface design and to suggest new ways forward.

Chapter 1 establishes the aims and methods of the study, outlines the organisation of the thesis in more detail, and indicates the contextual research that led to the research.

1.2 Aims and objectives

The aim of the thesis was to first discover more about the way 5 to 7-year-old children used computers by developing and testing a working interface appropriate to the ability of children. The intention was to improve the quality of interaction between children and computer interfaces they use.

To achieve these aims, the objectives were to:

1. Analyse observations of children in primary schools during the summer of 1994, prior to beginning the thesis.
2. Reflect on these observations by surveying standard studies of visual perception and psychology texts in a literature review and historical survey of educational developments in informational technology.
3. At the same time create a working multimedia product, referred to as the 'Research Tool' in the thesis, and intellectually account for the most appropriate design incorporating the prior observations and parallel literature review as far as possible during the Research Tool production period.
4. Test the Research Tool, summarise and analyse the results.
5. Suggest approaches to future design of multimedia products and further areas of research.

Arising from these aims was the research question:

What are the design features required to improve the quality of computer interface interaction for 5 to 7-year-old children?

The classroom context of the research was the current common practice at the time of three children using the computer, – an arrangement used by teachers to make use of scarce computer resources. Children in primary classroom were recognised to use computers in a variety of configurations but that the rotating of groups of three using the computer was a pattern observed in the contextual research to be the most familiar method used by teachers in the real classroom environment. The real classroom environment was defined as the typical everyday experience of a working primary teacher in which well-planned lessons are adapted to events – opportunities for learning – and flexible in terms of group and whole-class organisation .

Interface interaction was defined in terms of the new edutainment techniques emerging at the time: full colour graphic images with hotspots linked to other 'pages' or triggering animations, sound or video sequences and 'pop-up' boxes of text. Click and drag methods of interaction were only used in system software and in generic software programs. The new emerging edutainment techniques was an aspect of 'new media' referred to in the thesis – the integration of text, pictures, video, sound; and the increasing use of the Internet as well with the defining feature of interactivity.

The quality of interaction was proposed as being improved by developing a greater depth of engagement of children with the computer. Engagement was defined in the dictionary sense of attracting attention, employing, occupying (person, powers, thought) including emotional involvement or commitment, and the facility to improve the depth of engagement by greater use of the senses in the context of the limited technology available: kinaesthetic – in terms of greater use of motor activity with the mouse as a physical manipulation tool; auditory – the use of audio that enhanced interest and improved feedback; visual – improving the visual quality of interface graphics possibly including a simulated 3-D perspective. Engagement was also conceived as involving pleasure – a proposal arising from a combination of the subject matter, educational values and the contextual research and the depth potentially being enhanced by qualities familiar in radio production methods.

The methodology for answering the research question was qualitative. The methodology moves from the broad study to a focussed practical application through the creation of the Research Tool. The conventional fieldwork phase of a thesis has been replaced by the contextual research described below and in conjunction with the literature review informs the design and production of the Research Tool. A pilot study was used to test the methodology before the main study. The methodology is described in detail in chapter 4.

The Research Tool was a multimedia interactive version of songs, story, teachers' notes and graphics material from 'The Song Tree' an already completed BBC Radio children's primary music course for the 5-7 age group, *Starcatcher*, first broadcast in 1994. The title of the Research Tool was '*Starcatcher*'. The process of the development of the Research Tool as a CD-ROM has been recorded in chapter 2 of the thesis.

The accuracy of the methodology has been enhanced by new technology: first, applying new digital audio technology to make the recordings of higher quality observations and more effective interview transcriptions; second, using new computer database software to analyse the transcribed audio information more thoroughly. These new techniques are described in detail in chapter 4.

1.3 The organisation of the thesis

The thesis aims, objectives and contextual research are described in chapter 1. Chapter 2 takes the form of a description of the production, a journal, which critically reflects on the development of the *Starcatche*r Research Tool kept since the beginning of the creation of the CD-ROM in September 1994 (*The detailed log is to be found in the Fieldwork Diary: Part 1*). Chapter 3 is a literature review of, first, a chronology of significant events in the introduction of information technology in British schools and, second, a review of papers relating to the field of study. Chapter 4 demonstrates and tests the methodology used to evaluate the Research Tool. Chapter 5 describes the main study, the use of the Research Tool with children and presents a summary of the evidence. Chapter 6 is a series of written guidelines for improving the quality of computer interface interaction called the *total impact assessment toolbox*. Chapter 7 discusses the issues and implications arising from the main study and suggests areas for further discussion. The Appendices and Field Study Diary contain detailed information for reference. The structure of the thesis is summarised in Figure 1.1.

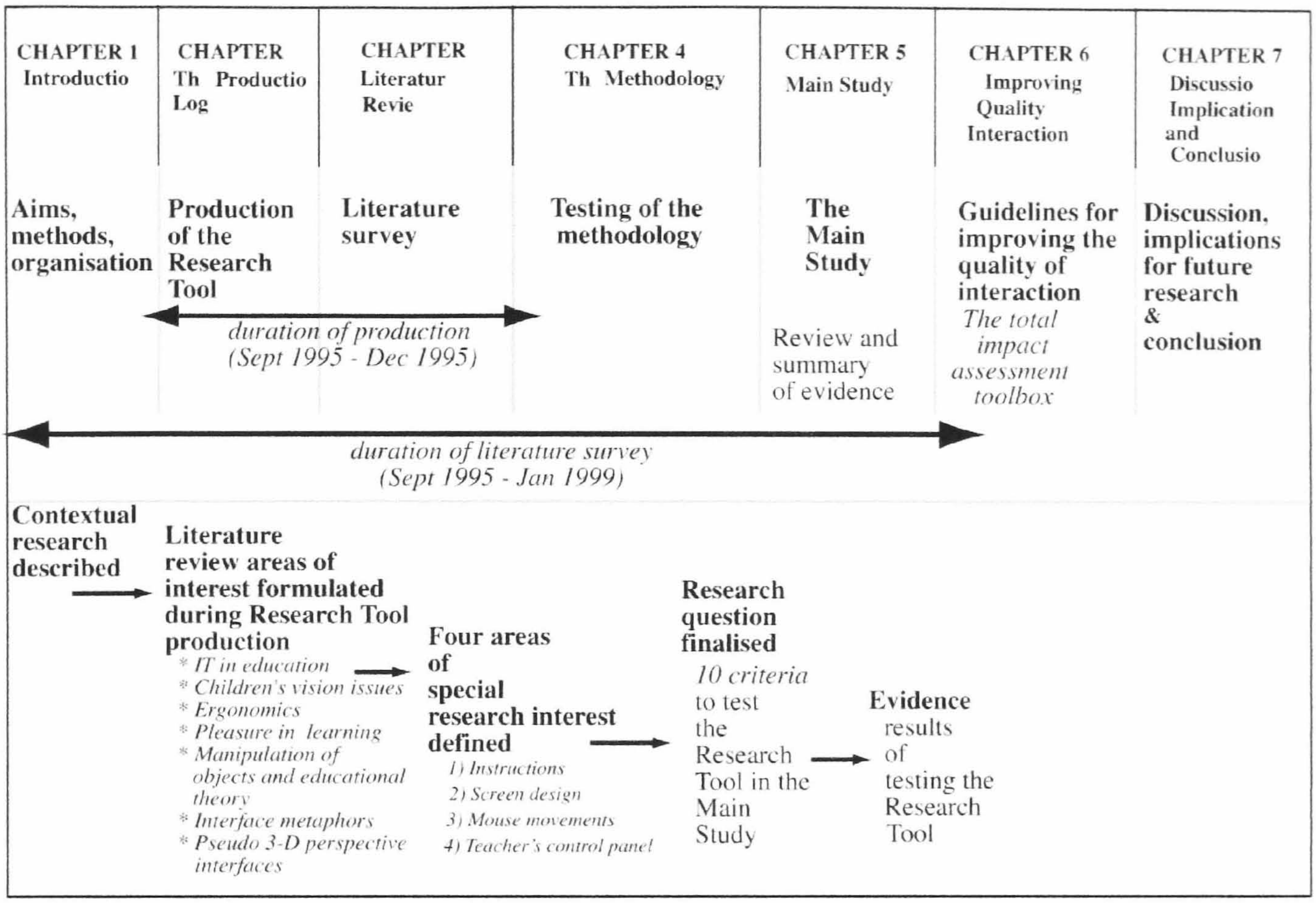


Figure 1.1: The structure of the thesis, in outline.

Figure 1.1 visually illustrates the relationship of the contextual research, the production of the Research Tool and the continuation of the literature review through the period of refining the methodology. The research was carried out between September 1995 and August 1999. The literature review ran concurrent with the creation of the Research Tool funded by the BBC whilst the researcher was seconded to the BBC Multimedia Production Unit at the Open University. The trials of the methodology, changes to the Research Tool and the main study itself were continued by the researcher after leaving the BBC, and during a period of training at the Centre for Electronic Arts at Middlesex University in 1997. The period of collating the research data coincided with the establishment of the researcher's Virtual Reality Photography business exploring the potential of Apple's QuickTime VR technology. Further research and redrafting continued in 1998 and writing up took place from 1999 when the researcher began work as a senior lecturer in digital production at West Herts College, Watford. The contextual research that stimulated the thesis is described in the next section.

1.4 A summary of contextual research

The section is a description of the contextual research prior to and determining the direction of the thesis. The period of contextual research began in April 1994, at the suggestion of the then Head of Department, Terry Marsh. The general aim was to investigate the potential of interactive learning and make the findings available to the Education Department. *(A summary of the titles of the reports created during this period is listed in Appendix 6. Summary and detailed classroom observations (1994) are to be found in the Fieldwork Diary: Part 1. The complete reports form Fieldwork Diary: Part 2. in Appendix 5: CD-ROM of the research Tool).*

The first task was to survey and acquire a collection of educational CD-ROMs for a departmental multimedia library for education producers' use. The second task was to take the CD-ROMs to schools and watch children using the software that had been acquired. The intention was to assess real educational value, rather than the advertised edutainment advantages.

The BBC's survey coincided with the beginning of the National Council for Educational Technology (now the British Educational Communications and Technology Agency, BECTa) CD-ROMs in Primary Schools Initiative in 1994. The Hertfordshire Information Technology Centre (ITC) was involved in the Initiative and through them contact was made with a range of schools that had been provided with computers and software as part of the scheme. *(See Fieldwork Diary Part 1).*

Permission was given by Hertfordshire ITC to visit 12 of the Initiative schools during the summer term of 1994. The audio interviews with teachers and children were recorded while they were using the computer and the transcripts written up as reports. Some schools were visited on several occasions. A summary of the observations was prepared. These early observations represent the contextual research, a personal view and a collection of perceptions carried out before, but leading to, the thesis. The contextual research has guided the direction of the Research Tool design and the focus of the literature review. The following is a summary of the key points from the contextual research. *(For the detailed report see Fieldwork Diary Part 2.)*

1. Children appeared to ignore icons in the corners of the screen. The subjective observations appeared to suggest preferences for particular parts of the screen. There appeared to be a preference for the left and right of the middle area of the screen. They also appeared to press some buttons repeatedly, and ignore others completely. They also clicked anywhere quickly and at random and frequently moved to the next screen using the hotspots without attempting to read the contents of the screen.

3. Children were also observed working away without any sense of time, chatting, concentrating intently and expressed their pleasure in the educational materials in a manner familiar to the quality of their experience with computer game playing.

4. Observations raised the researcher's concern of the computer's physical form as in an adult product. The CD-ROM disc case, keyboard and the mouse were too big for a child's hand. Even the best-designed trolleys were too small to accommodate the computer, keyboard and monitor. From these practical issues came serious concern that in the process of learning children have great difficulty holding the mouse, manipulating the cursor over hotspots, looking at the screen, holding the mouse still whilst clicking on hotspots and carrying out click and drag movements.

5. Pupils continually appeared to have difficulty 'finding their way' around the software, becoming 'lost' in the multimedia activities, expressing their displeasure by going off-task and displaying anxiety. There was the difficulty of children recognising the meanings of icons and the role of lettering, colour and feedback responses expected by children. A focus of the researcher's interest developed into questioning the appropriateness of language, figure/ground relationships, the number of icons, their colour and location on the screen, icons and sounds and the hierarchy of icons used to navigate through the software.

These observations guided the interest in the design of the Research Tool and also the direction of the literature review.

The detailed reports were shown to the BBC Education Directorate at the end of the summer term 1994. The findings were also presented at the time to a number of other researchers in the field including the National Council for Educational Technology (NCET), British Aerospace Sewerby Research Centre, the Open University Institute of Educational Technology, and staff at the Middlesex University School of Education. It was at this point that staff at the School suggested the contextual research could be pursued further in a formal academic context.

Chapter 1 has provided a background to the main body of the thesis identifying its aims demonstrating the formative interests, the experience and the contextual research of the researcher to demonstrate it has clarity of focus. As already indicated, the development of the Research Tool was carried out in parallel to the literature review. Those aspects of the contextual research incorporated within the commercial production schedule for the Research Tool are indicated at the beginning of the next chapter. The development of the Research Tool is now described in chapter 2.

Chapter 2: The Research Tool: about the production

2.1 Introduction

Chapter 2 is a report of the development and production of the Research Tool to be used for the main study. The chapter is an introduction to the Research Tool, the context and history behind its origination, and the features incorporated in the construction and design. The Research Tool was a multimedia CD-ROM product called *Starcatcher* using the audio and pictorial assets from programme 1 of *Starcatcher*. *Starcatcher* was the title of a 10-programme sequence in the 'Song Tree' series, a BBC Education Radio Primary Music Course for 5 to 7-year-old school children. The daily log of the production process and the staff involved is described in detail (*see Fieldwork Diary Part 1*). References in the chapter to children using the Research Tool are to tests of the software during Stage 1: the first methodology pilot, very early during the Research Tool testing period. The references are part of the contextual research and not to the classroom evaluation which forms the main study of the thesis. The CD-ROM containing a working model of the Research Tool is included in *Appendix 5*. The Research Tool was created using Macintosh software. The software ran on a Macintosh computer taken to the schools during the testing period. The final version was planned to be PC compatible but for technical reasons (recently updated PC operating systems) is only available in a Macintosh version on the CD-ROM.

The Research Tool began as a commercial project commissioned by the BBC in conjunction with the thesis. The researcher planned its design informed by the contextual research summarised in chapter 1, and by the literature review as indicated by cross-references to chapter 3. The interactive multimedia elements in the Research Tool were assessed using the research methodology described in chapter 4. The researcher's role in the production stage was to project manage the commercial production process of the Research Tool, supervise the contracted graphic artists and a programmer (Mike Saunders), whilst reflecting on developments in an academic context.

2.1.1 The original aims of the BBC project

The aim of the BBC project was first, to explore the feasibility of transferring radio programme resources – the accompanying teachers' notes, children's worksheets and graphics – to a digital multimedia product. Second, to explore whether the original learning aims and objectives could be transferred by the use of interactive multimedia.

The aim of the Research Tool in the context of the thesis was more focussed. It was to investigate the interface design issues, especially the potential for improving the quality of interaction through greater depth of engagement that arose from using the radio and pupils' handbook activities resources in digital multimedia form. It was not to investigate what musical knowledge children had acquired using the new technology or redefine the aims of teaching music in interactive terms or explore a single new aspect of learning music through interactive methods. These options were rejected due to financial and time constraints.

2.1.2 The decision to use Starcatcher

The decision to choose the radio programme called *Starcatcher* (*see Appendix 4*) was made within the feasibility brief of the BBC Education Directorate. The choice was made because of the very favourable response of schools and press during the previous Autumn Term Press Launch in 1994, when the *Starcatcher* series was first broadcast to schools. The project reflected the intense interest in multimedia including the creation of a new Multimedia Research Centre at White City. The researcher was given the task of managing the project and then proposed that it should be part of rigorous investigation within the thesis.

The researcher project-managed the production process according to the BBC's anticipated professional timescale for a multimedia project. This was set to be a 3-month schedule from 1st September to 31st December 1995. The researcher also designed an interactive and multimedia structure within the existing budget constraints, and within the anticipated future Directorate multimedia production cost limitations of £20,000. The production team included two artists creating the graphic images and the multimedia designer programming the interactive aspects according to the researcher's brief, but also made suggestions for improvement of the design as part of the iterative process. The researcher was also able to speed-up the production by preparing the outline interactive design using Macromedia Director software to demonstrate early trial models and by digitising the resources for the programmer. The work included digitising sound files from the original radio programmes and scanning in and preparing rough illustrations for the artist to develop.

This chapter is the record of the creation of the Research Tool CD-ROM and also contains references to the contextual research and the early stages of the literature review which were incorporated as features in the software. There are references to children's responses. These relate to a first methodology trial during the production process in December 1995 at a primary school in Hertfordshire.

2.2 Incorporating the literature review in the Research Tool

Three desirable elements that enhance the quality of interaction identified in the contextual research have been directly incorporated in the Research Tool. These three elements were: first, the need for a control panel interface for teachers and a simple navigation structure: second, the potential for greater depth of engagement through a recognition of eye physiology and children's vision issues; and third, the potential of a pseudo 3-D storytelling interface using a simulated 3-D perspective. From the creation process came recognition of the value of greater engagement through manipulating objects using the mouse. These were not generally recognised subjects for education interface design at the time the research was carried out. They are described next.

The preliminary observations of the research in progress were published in the *British Journal of Educational Technology* in April 1997 (*see Appendix 2*).

2.2.1 The need for an interface for teachers

The contextual research regarding the difficulties of teachers using 'edutainment' CD-ROMs in classrooms led the researcher to propose a control panel interface in the Research Tool solely under the control of, and for teachers. The control panel allowed teachers to set up the computer quickly and easily, but more importantly organise the differentiation and progression of children and their work. This form of organisation was not available in any of the CD-ROMs listed in the NCET material at the time. A form of control was available in some commercial products such as DISCUS and Wiggleworxs but using the technique of users choosing levels and sections. The concept of a teachers' control panel in the Research Tool was proposed using a different approach – the transfer into a digital medium of three very familiar aspects of normal good classroom practice. These aspects were: first, to be able to set tasks that can be completed within the normal time span of a lesson: second, to allow children to work on material which is appropriate to their own level of ability (differentiation); and third, to add further activities which develop children's ability (progression). The concept of a teachers' control panel was a reaffirmation of the traditional 'bottom up' model – a teacher led development of education resources.

The 'bottom up' concept underlying a teachers' control panel was very much against the attitudes of the time that the 'edutainment' multimedia CD-ROM software was easy to use and children only needed to use it to be able to learn – a popular view criticised by (Hawkridge, 1989) (*see chapter 3, p. 67*). A teachers' control panel in the Research Tool was a design decision that gave teachers a method to manage the resources on a CD-ROM – to 'break up' the mass of content and allowed them to judge what was suitable for their class. The teachers' control panel also allowed teachers to overcome one of the persistent barriers against using existing 'edutainment' CD-ROM software by offering a facility to take a quick look at the contents of a CD-ROM in minutes rather than hours.

2.2.2 Recognition of eye physiology and children's vision issues

In the light of his observations during the contextual research of children having problems viewing a computer screen, *(summarised in chapter 1, p. 6)* the researcher suggested to the project programmer that the screen displays should be visually simple and uncluttered. Also, that the centre of the screen and an oval form for graphics should be used in preference to the edges. These suggestions are in part a response to Bruner and Mackworth (1970), and to research by Gregory (1974) *(see chapter 3, p. 79)*. It was necessary to go back to these early references for eye search, because the subject was not the concern of educational research at the time of the literature review. Findings from this research informed the contextual research accounting for the fixation of attention around objects by children of a young age. Though Mackworth and Gregory wrote in the context of using conventional still pictures and direct physical manipulation of real toys, the technology in the Research Tool enabled the principles to be applied to a new interactive screen context. Some of the artwork lent itself to having a simulated 3-D perspective – the property of being looked down onto or into – directly applying observations about 3-D visual search by Enns (1988), Stoper and Cohen (1991) and others *(see chapter 3, p. 83 and p.85)*.

2.2.3 The role of manipulation of objects using the mouse

As the literature review was conducted in parallel to the creation of the Research Tool the review informed the desirability of allowing children to manipulate information on the screen using a mouse. The capability was incorporated in the design of the Research Tool. The realisation was assisted by the subject – percussion music using manipulating beaters and selecting sounds – and availability of the latest techniques of Lingo programming in the software (Macromedia Director™). Once the concept was explored and demonstrated to be workable in the first plan of the software, literary references to activity-based learning and speech by Piaget (1952) and Vygotsky (1978) became the focus of a reiterative process of re-evaluating the potential. Further study, explored the concept of pleasure in activity and learning by Csikszentmihalyi (1992), noting valuable effects of total involvement, absorption and pleasure during physical activity, all suggested an activity interface could involve children in a deeper physical and emotional way by using moveable icons rather than clickable icons. At the time click and drag operations inside multimedia products were in advance of common educational software programming. In many multimedia products the mouse activity is confined to clicking buttons and highlighted hypertext.

It was for these reasons that the Starcatcher interfaces employed mouse operations, which children could use as an extension of their hands, as tools which created a direct relationship between them and tasks. If the mouse pointer arrow changed it became one of the standard pointing hand, hourglass or clock symbols. In the Starcatcher interface the mouse arrow changed to become a tool, for example a musical beater. During the early production tests, this feature together with the comprehensive use of high-quality sound appeared to change the frenetic clicking activity of children to more focussed activity. Also the screens were designed to have a dissolve effect and not to disappear quickly so children have time to recognise that a change is happening and avoid a surprise or shock reaction.

2.2.4 The potential of a pseudo 3-D storytelling interface metaphor

The discoveries in the literature review about the value of a 3-D interface metaphor were only applied to the story element of the interactive design, rather than every activity screen, because of the limits of time and cost. There was also a technical problem, because the visualising of even a pseudo 3-D perspective interface conflicted with the operation of the mouse and its manipulative features – the software could not be made to display dragging objects across a 3-D background – without revealing white pixels around the moving object. Only the story interface in the Research Tool was designed to create data to analyse the effectiveness of a 3-D interface container metaphor. The story has a pseudo or simulated 3-D perspective interface which was used to explore the effects of children being able to physically place themselves in the story. The activities work in a simulated 3-D perspective (in 2-D) because of the limitations imposed by the production deadlines. The design for a 3-D storytelling space was based on a container with shading for depth and a rear 'wall' reduced in height to create the impression that the scene is being observed from above, the optimum visual search position as described by Maddess et al., (2000) and others and discussed in more detail in chapter 3 *(p. 86)*. The application of the container concept originated in the work of orientation and ontological metaphors of Lakoff and Johnson (1980) described in chapter 3 *(p. 105)*.

The origin of the simulated 3-D storytelling space concept is developed in more detail here. The drawings for the story sections of *Starcatcher* were 3-D perspective sketches drawn by the researcher. The ideas were first explored in Howarth (1997, p. 135) and visualised in Figure 2. 1 below. The result is the concept of 'Radio Rooms' formed by two box shapes positioned side by side, with an open doorway between. These are drawn as viewed from above and at an angle. The oblique viewpoint has the potential advantage of faster recognition times for the observer (Enns and Rensink, 1992) and (Maddess *et al.*, 2000).

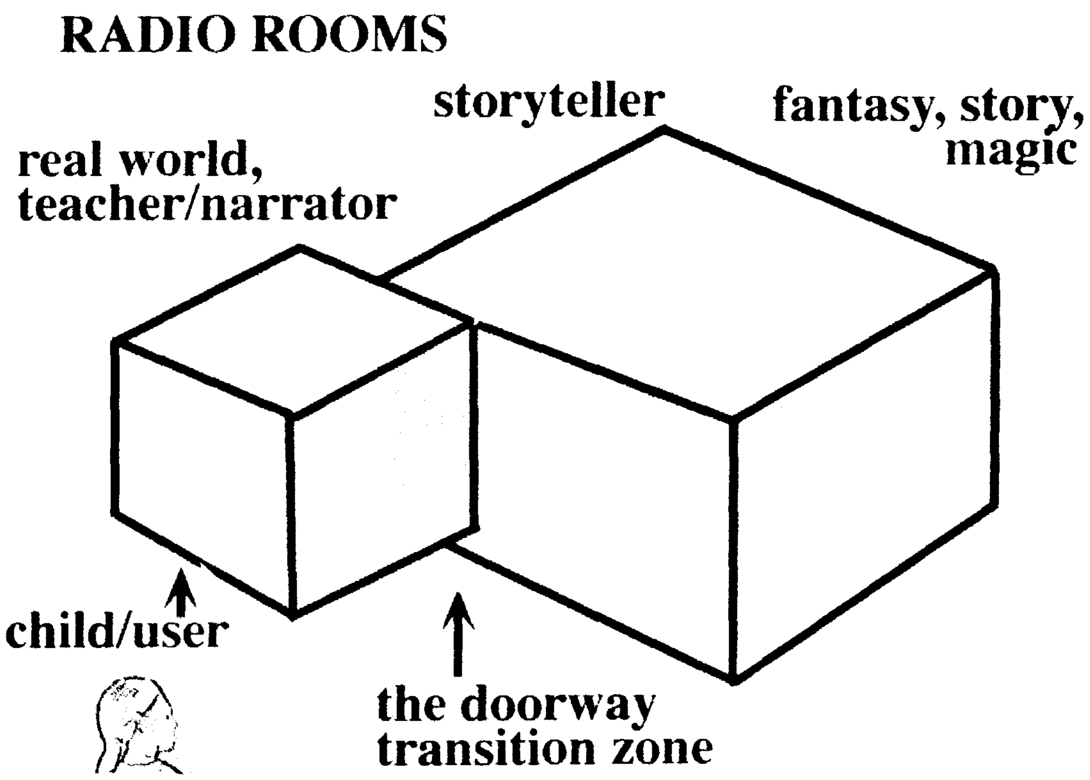


Figure 2.1: Visualisation of a radio script represented in 3-D. (Howarth, 1997, p. 135)

The concept of a narrator's room and a story action space had resonance with the creation of radio programmes in the physical environment of studio and control room and informed by the existence of navigable routes through text in 2-D by Chapman (1987). He stressed the visual process (*see Figure 3.12, chapter 3, p. 110*) that affects clarity of understanding through visual eye scanning, not the 'choose your own adventure type of books' of the early 1980s with their multiple choice story routes leading to different endings. Furthermore, in the Research Tool, each child could also click on icons of four children – by inference users – and drag the images so users could have the experience of 'taking themselves' into the narrator's room and 'into' the story (see *Figures 2.13-2.15*). The proposition was that all these elements physically involve users to a much greater extent than the traditional 'page' metaphor. The sequence of screen shots developed from the diagram above can be seen in the next section.

Protherough (1983) also considered looking down on a scene in a story might be a popular concept in literature. As a result the researcher instructed the artist to create the background in oblique view. Also the graphic images of children were drawn facing into the picture and viewed slightly from above. The aim was to reinforce the sense users may gain from being part of the story by looking over the shoulder of the person they are manipulating (clicking and dragging) in a process that is comprehensively more visual and physically absorbing (*see section: The role of metaphor in interface design, chapter 3*). The technique has also probably origins in cinema and is standard practice in current visual worlds software. The preference for third person 'over the shoulder' view of a personal icon has also been observed more recently by researchers in the Vertex project, (Bailey and Moar, 2001, p.11)

The radio story sound effects were used in the visual transitions in and out of the narrator's room and the fantasy space. In the case of this example the transition is through the window of the room where Granny – the narrator – is sitting, to the night sky where the story unfolds.

The three components: the teachers' control panel proposal, recognition of eye physiology and children's visual issues, and the 3-D metaphor potential that form the major practical influences on the Research Tool were informed by the contextual research and the literature review at the early stage of the production process.

2.3 Developing the interface design

An achievable plan was essential to turn the original teaching resources into interactive activities within the time limit. Brainstorming techniques were employed to explore different methods using visualisations of outline perspective drawings of layers showing the connectivity in a 3-D simulated view. Later, the original artwork was added. The visualisation technique was also an effective way to communicate ideas to management and aid clarity of discussions.

Planning Interactivity

The programmer needed the detailed formalised list of requirements provided in the form of the design brief. The amount and complexity of the specifications necessitated a written reference and a log to keep track of the digitised assets in each of the main subheadings of the project: the main menu, the children's menu, the six activities , the story and the song. Within each subheading, the interactive brief was organised in two sections: in terms of the artwork components needed and a description of the interactive operations required for the artwork elements to function. Then a recheck was required to confirm the interactive ideas had reproduced the activities as described in the teachers' notes.

Transferring radio resources to multimedia

The process of planning each interactive brief was outlined in chapter 1 and consisted of studying the *Starcatcher* teachers' notes in detail. The process involved transferring the original aims and educational objectives of the radio series into multimedia format. These aims and practical activities were clearly and simply laid out in the teachers' notes in a format that was well tried and tested. The content of each programme was also defined in detail with the aim of providing teachers with concise information needed before the tapes are played to the class. The ready prepared artwork, audio material with a clearly defined story line and activities, all to recognised BBC education standards and production values, speeded up the planning process. There were scripts available for each of the programmes and the tapes for each programme were listened to at the planning stage. The teachers' notes even defined interaction in terms of children's activities with the tape and booklet in a classroom situation. The interaction being defined in educational terms so concisely made it easy to look for ways to plan complementary activities in computer interactive form on the computer screen.

The song, story and six activities were given equal value. The six activities in their final order were:

Activity 1: Children hear and see demonstrated the main phrase of the Holst's 'Jupiter' (To Thee My Country) theme with the aim of identifying a tune. They recreate the tune and their own tune using the same notes.

Activity 2: Putting into a boy's pockets 'star', 'shooting star' symbols to aid familiarisation with music pattern.

Activity 3: Putting planet symbols into a series of pockets to make a rhythmic pattern. Children learn about the structure of musical notes, using the syllable pattern of words as examples.

Activity 4: Click and drag spelling of 'star', 'moon' and 'sun' from jumbled sets of letters.

Activity 5: Creating star tunes using percussion instruments – choosing an instrument for each star, moon and sun picture.

Activity 6: 'Choose a music sound for different stars' – 5 stars each with different instrument sounds. When each star is chosen a tune plays.

The aim was to explore whether the contents of a whole educational radio programme could be transferred to the computer. The overall design was based on following existing professional experience of music radio production. The motivational interest should come from the emotional element provided by the story (a quest). The fun element should come from the song (joining in the repeated sections led by the narrator during the broadcast). However, the ideas for interactivity came from the teachers' notes activity information traditionally used in class during and after the broadcast. The aim of the Research Tool was to maintain the theme and approach in the new form of interactive media and to try to incorporate the qualities of pleasure and involvement inherent in the radio series.

The project management methods for creating the Research Tool were: a definitive written brief as a description for briefing the programmer and communicating progress to management; a production schedule; and also a log as a reminder of the large number of decisions taken. The process informing the design drew on the traditional radio production briefs with defined educational objectives and methods of achieving them in audio and visual terms, but now with an important addition – the methods of multimedia interaction (*see The BBC Starcatcher project plan, timetable and production log in Part 1: Fieldwork Diary on accompanying CD-ROM*). At the time, the attention paid to conventional computer instructional design was declined in favour of an exploratory method based on traditional radio production values.

2.3.1 The teachers' control panel menu

The teachers' control panel menu or title menu used the original radio series book cover picture theme, but the figures were moved in from the edges of the frame so children would not find visual search difficult or have to manually move the mouse too much. The quality of Granny's facial detail was improved. The star was placed left of centre to allow more room for the title phrase with star buttons spaced out around the phrase to be used for the teachers' controls.

Figure 2.2: The teachers' control panel menu page.

The key feature of the title page or teachers' control panel menu interface (based on the contextual research) was that children cannot start the program themselves until the teacher has organised the selection of activities. Users must wait until teachers switch on the access to the stars control panel by holding down the Alt + Apple (Research Tool Macintosh version) and simultaneously clicking on a star to select a function. Typically teachers would be expected to prepare the selection before a class session starts.

Figure 2.3: The 'Select all programme resources' option menu in the teachers' control panel.

The first star in the sequence of 7 around the title activates the 'Select all programme resources menu' (*Figure 2.3*). A design change was made to simplify the selection of resources by creating this menu of the teachers' control panel which allowed teachers to make a decision whether to include all the resources for just one programme. An early idea was that could make a conscious selection of every element in all programmes before starting. The new option was provided to help teachers who might consider switching on elements from different menus too complicated. From installation, three mouse clicks are all that are needed to enable the program to be set up. For the Research Tool purposes, though all the code in Macromedia Director™ is in place for future commercial production, only resources for the first radio programme are active.

Figure 2.4: Close-up of teachers' control panel buttons.

Seven stars in this illustration of the top right corner of the interface are buttons that switch on or off with the Alt + Apple (Macintosh) keys from each of 7 lists. From top-left to bottom-right: Select all programme resources, Story Options, Song Options, Activity Options, Sound Controls, Teachers' Notes, Star Words.

The idea to use the Orion constellation, a key theme in the broadcasts was replaced by a simple 7 stars arrangement around the title phrase. The reason was that though Orion was a theme of the story in the radio programmes, the concept was visually too advanced for the age group. The stars were also deliberately designed not to be too prominent. It was thought that children might see their teacher set up the program and try to click on them. However, children took no interest in this aspect during the first trial (*see the first methodology pilot, section 4.2, chapter 4, p.126*) perhaps because the process only occurred at the beginning of the session before children approached the computer.

Figure 2.5: The Story Options menu.

The titles on the Story Options menu of the teachers' control panel were a list of the story episodes (one per programme) – 10 in all. A rollover highlights the choice and a mouse click selects the item. Only the first story was active.

Figure 2.6: Song Options menu.

The Song Options menu shown *(Figure 2.6)* allowed teachers to choose whether they want children to be able to repeat the verse or the whole song. The original aim was to allow children to be able to replay each word in the song. The intention was to use QuickTime movies to control the access to the sound files, but this had to be changed because the method would not have guaranteed consistent running on different machines. The 'Catch a Falling Star' song featured in the first programme was left out because of the lack of time to program the elements into the Research Tool. However, the concept of the song was incorporated in the activities i.e. stars in pockets. In the first draft design of *Figure 2.6*, the un-highlighted lettering was too dark and this effect was made worse in the PC version, caused by dithering the images to 8-bit colour. The problem was solved by re-versioning the colours of the graphics in the PC version of Director during the cross platform final production.

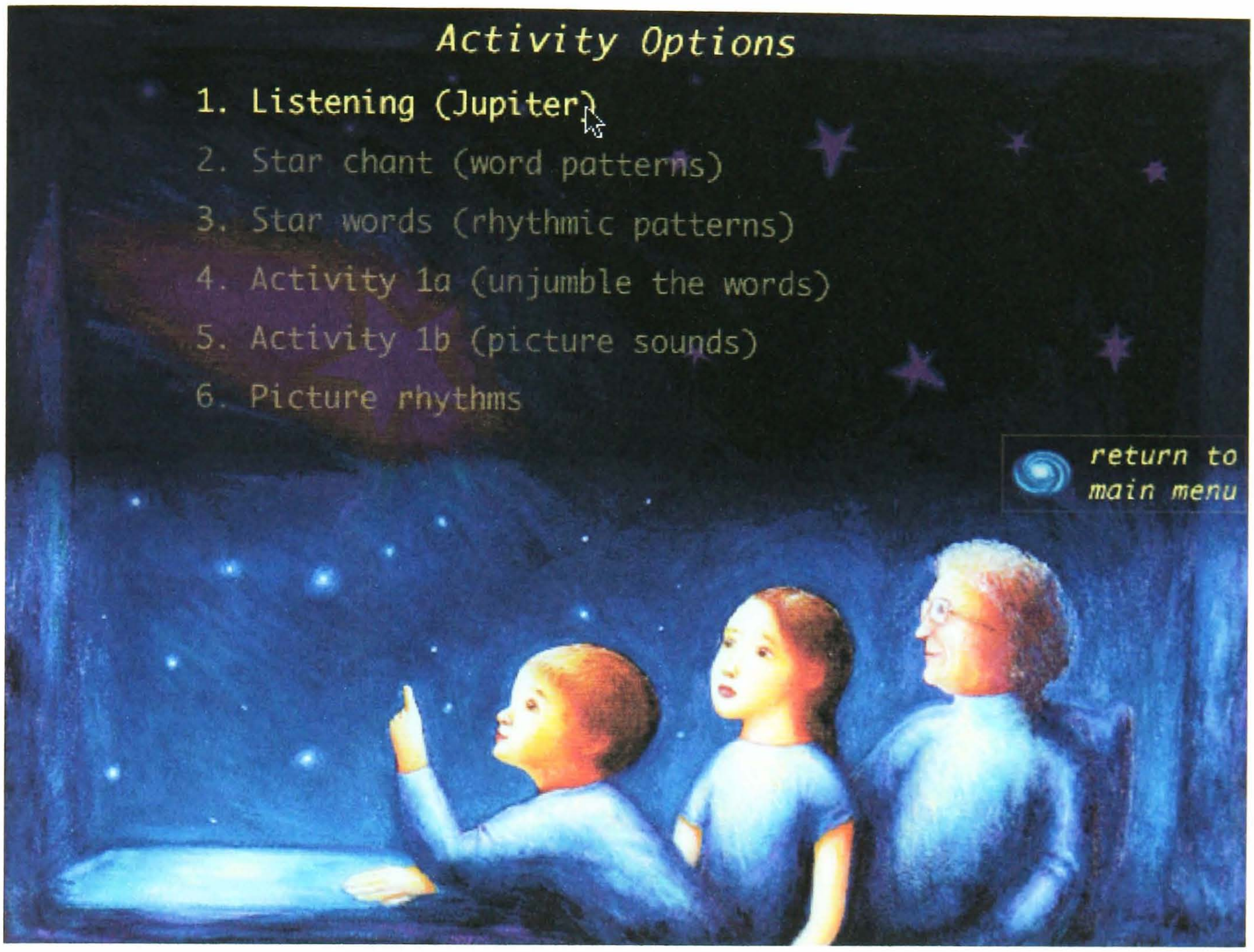


Figure 2.7: Activity Options menu.

Each of the 6 activities in the Activity Options menu *(Figure 2.7)* of the teachers' control panel is selected by highlighting and then clicking on the listed item. The intention was that in the final commercial version of the Research Tool, 40 activities, all of those existing in the radio programme series could have been listed in this menu. The structure was defined by the order in which the ideas appear in the radio programmes and reflects a progression of activities. Teachers can reorder these, but for simplicity of use for the main study the option of 'All on' using the 'Select all programme resources' menu was chosen.

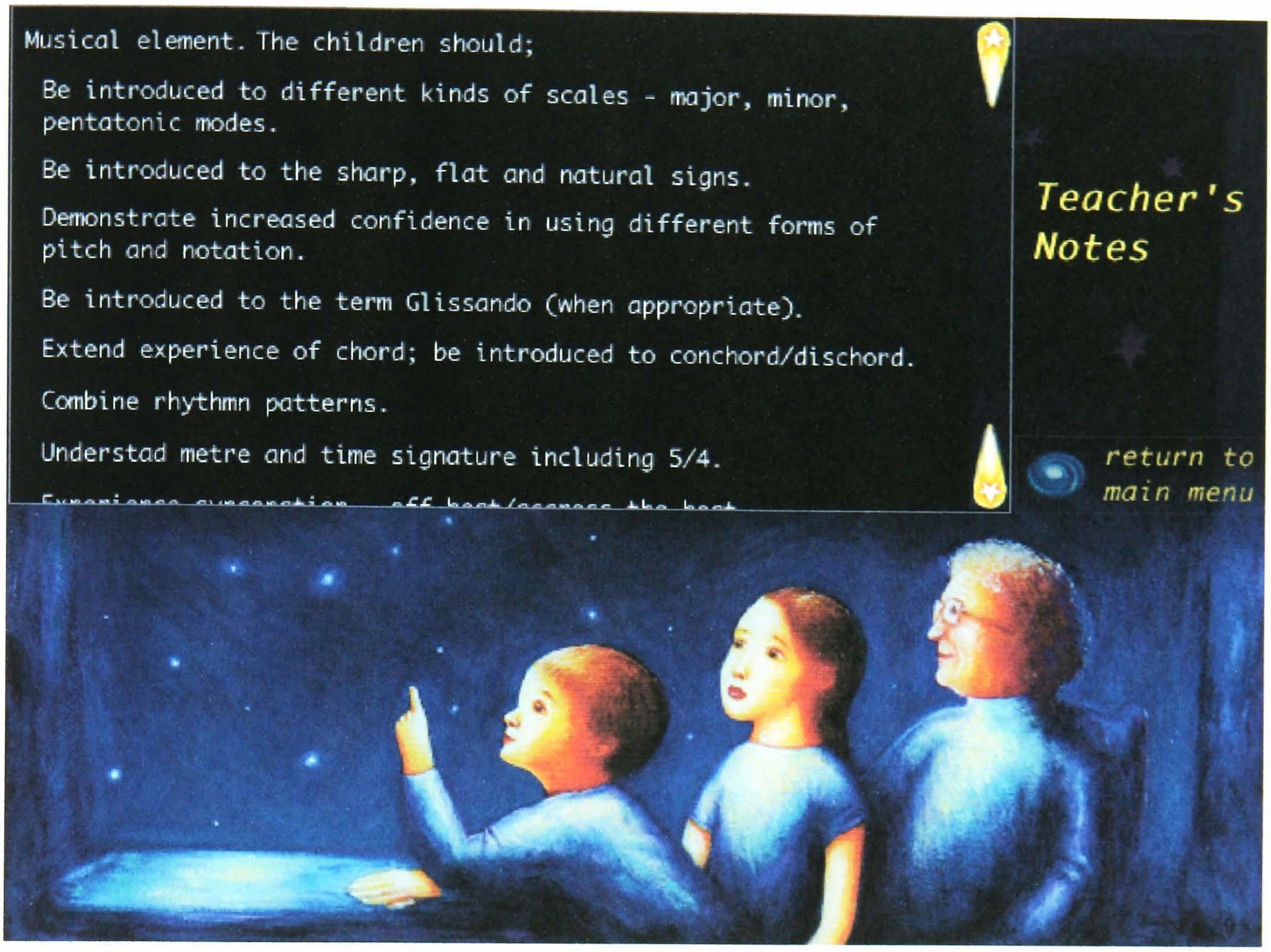


Figure 2.8: Teachers' Notes menu.

The Teachers' Notes menu *(in Figure 2.8)* was intended to contain a straightforward scrolling screen of the teachers' notes with the ability to print them out. It was not possible to reproduce the entire teachers' notes in the Research Tool because of pressure of time, but the principles of its potential have been demonstrated. There was also no easy facility to programme the ability to print out the notes provided in the pilot, but this could now be easily achieved using the current version of Director which allows the use of Portable Document Format (PDF) pages to produce well-laid out copy. It was anticipated that would just print off the notes right away and not use the on-screen scrolling facility. It might be desirable that they can also choose a section to print e.g. by programme. Alternatively the whole text file could be downloaded to the computer.

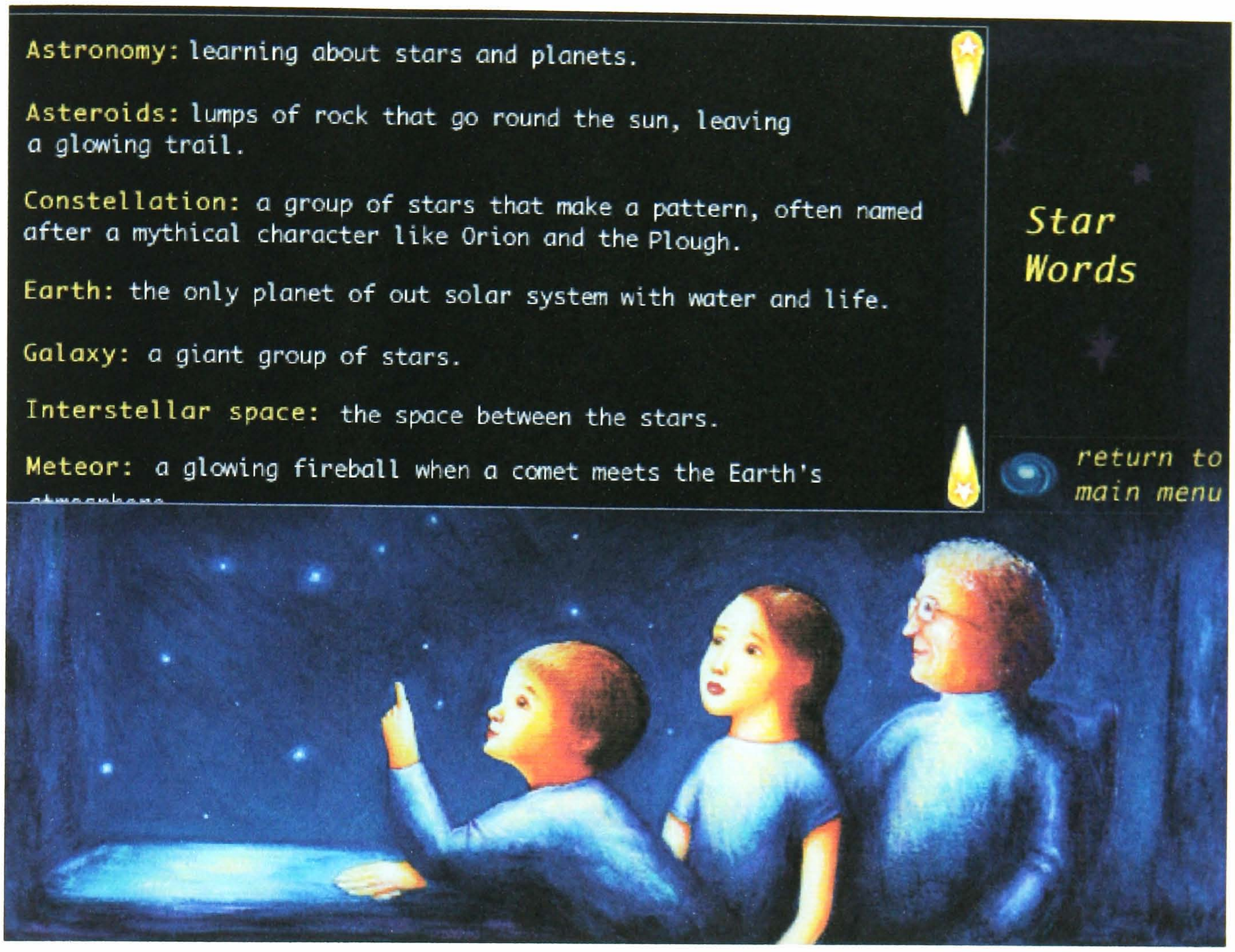


Figure 2. 9: Star Words options.

The Star Words options menu originated as the glossary of terms in the teachers' notes. The explanations were presented in text and audio at an appropriate language level for children to understand. This element did not form part of the final version of the Research Tool because it was difficult for the programmer to uncouple the code from the separate teachers' control panel section at a late stage in product development period. However, the element was left as a practical technical demonstration of the potential for making previously inaccessible material in the radio broadcast teachers' notes available to children. A 6-year-old child who recorded the phrases read out the words without any problem. (*See Example of transfer of resources from teacher to child access, Fieldwork Diary on the accompanying CD-ROM.*)

Figure 2.10: Sound options.

Teachers could adjust the volume level of all the playback sound and also turn the sound instructions on or off in the Sound options menu *(Figure 2.10)*. The reasons for adding this menu were first, the problem of controlling the volume on the computers in school at the time, as the controls were on the back of the machine; second, in the contextual research, teachers vehemently complained of the sounds, particularly the repetitive and educationally unjustifiable sounds. The notes on the menu screen remind teachers how to control the CD-ROM. In the first draft of the Research Tool there was also an option allowing teachers to give children control of the teachers' menu. There was also the place where teachers could switch on/off the ability of children to replay a line or verse of songs, a choice reflected by the appearance of a small icon at the beginning of each line or each verse. The flexibility provided by these easy controls allowed the Research Tool to be effective in the study of the use of sound instructions.

2.3.2 The children's menu

The children's menu (*Figure 2.11*) is no different in appearance from the teachers' menu (*Figure 2.2*). The original intention was to make the children's menu a separate piece of artwork. However, following the teachers' activation, the menu is now 'live' i.e. the rollovers, sound, and links operate and are available to children. The Director software layers system allows the same piece of artwork to be used so children's interactivity was achievable by adding code turning the three figures into buttons.

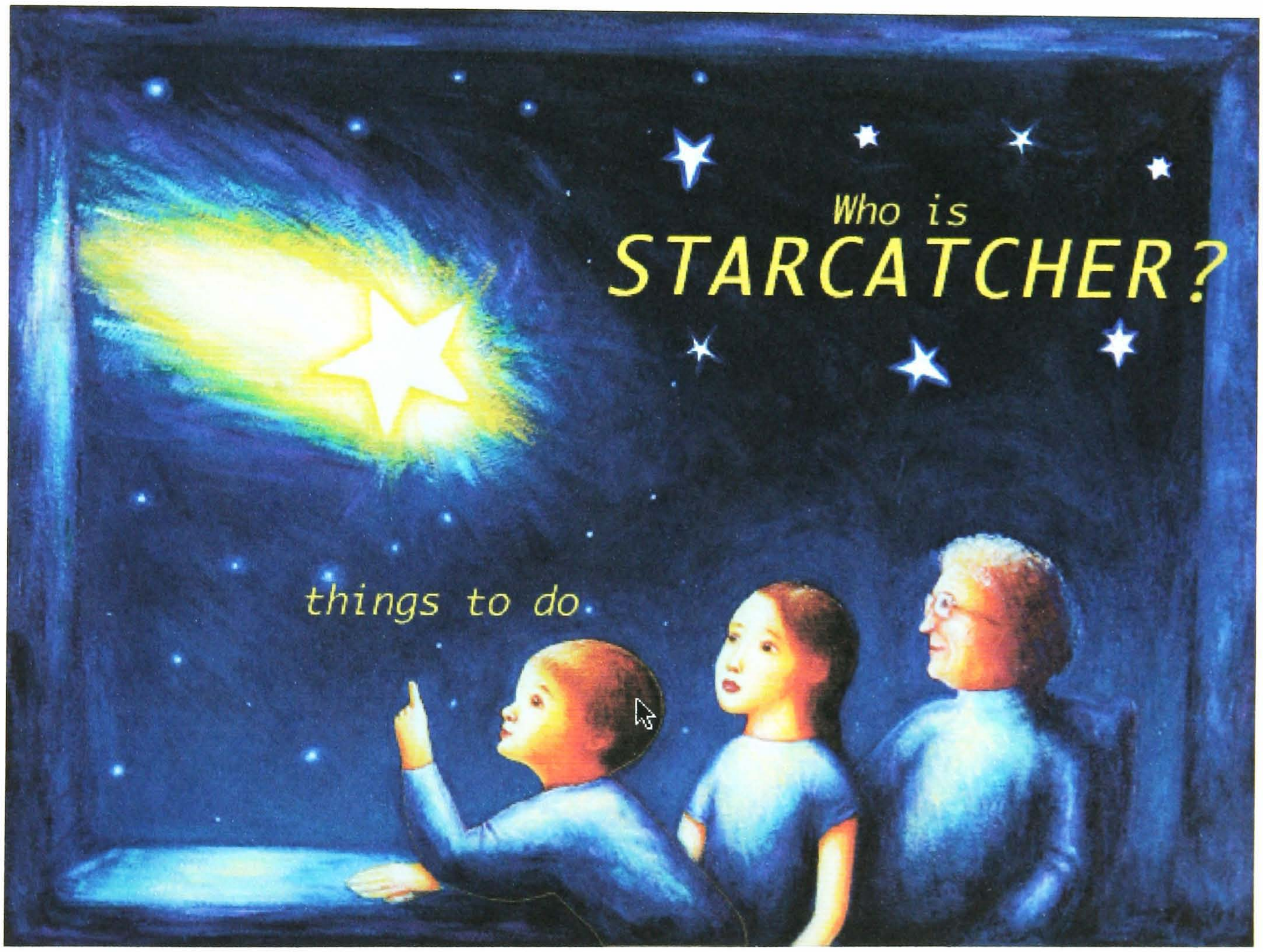


Figure 2.11: The children's menu.

Each figure highlights as the mouse rolls over it and a text label appears (Things to do, Stories, and Songs). Each text label is accompanied by an audio instruction. Clicking on the boy, girl or grandmother figure gains access to the different sections.

The researcher considered that merely transferring the pamphlet title with the word 'Starcatcher' to the screen gave insufficient guidance to users. Originally, it was envisaged that the Research Tool might be an entirely teacher-controlled product, with a verbal instruction to the class before pupils used the program, or that pupils would listen to the radio programme which would provide all the impetus necessary. The reason for this approach was in line with conventional attitudes to the control of BBC Radio resources by teachers and to create a product that teachers felt confident in using, because they could define its relation to class work. The implication of the teachers' control panel design decision was specifically assessed in the research methodology. However, to ensure the software could be used by children on their own, in keeping with the current design of popular edutainment CD-ROMs, the researcher changed the design brief to add the question 'Who is Starcatcher?' to appeal directly to children. This functionality could be achieved by adding audio roll-over instructions to the original text-only instructions. Also the audio instructions were changed to ask children to take action.

Once it was observed in the first methodology pilot how well the combined audio and visual elements appeared to work with users, the audio instruction element and its inherent discovery approach were added to all the activity pages. The most obvious result was that a teacher need not explain the activities – children could understand and get on with the work without mediation by an adult. The second result was that the discovery theme, implicit in the radio programme structure could become an explicit goal in the multimedia context.

The idea of creating a game to achieve the goal was proposed, but rejected because there was never any final revelation in the broadcasts. The decision to just set the audio (and textual) challenge as 'Who is Starcatcher?' was because the first methodology pilot results made it clear that the age group were quite satisfied with the wonder and mystery of the search without the need for a resolution. The result was an open-ended, exploratory, non-directed opening theme that is a typical educational radio approach that might provide an addition to the visual and kinaesthetic levels of engagement – by using emotion. This is a familiar technique used by education radio producers, and transferable to new media as an informed and focussed method. The 'Who is Starcatcher?' phrase sounds 5 seconds after the teachers' menu choice is first made. Also the phrase sounds after the mouse was idle for ten seconds. A sense of mystery and anticipation is further enhanced by constructing other audio files with encouraging phrases that appear when the mouse rollover functions happen i.e. 'Sing along and find out', 'Hear a story about him', 'Hear some stories about him'. The same technique of encouraging depth of engagement by using open-ended audio instructions was also applied to phrases in the story interface too:

> 'Let's go and see Sam and Stella's Gran.'
> 'She'll tell us a story too.'
> 'Do you believe in Starcatcher?'
> 'We all do.' (All four children speak.)
> 'Gran, tell us about Starcatcher, we won't tell a soul!'

The responses from children were encouraging in the first methodology pilot. Children listened to what was said. They discussed what to do and talked about the images. They did not rush and click on any icon. The response of the researcher was to add similar audio instructions to all the activities in the final version of the Research Tool. The effect of the opening interface also informed the design of the observation techniques in the research methodology as described in chapter 4.

2.3.3 The interactive song screen

The interactive song screen in Figure 2.12 was used to explore one of the traditional features of education radio broadcasts in a new media environment, and particularly music and movement programmes: children are encouraged to sing along (and interact) with the programme under the encouragement of the programme narrator. Typically, a page of music will be read or sung and repeated with children's voices. The section will then be repeated with just the background music or even an instruction to pause the tape so children can work with teachers. Often the section is then repeated again so children can all join in and compare their results (reinforcement) with the original.

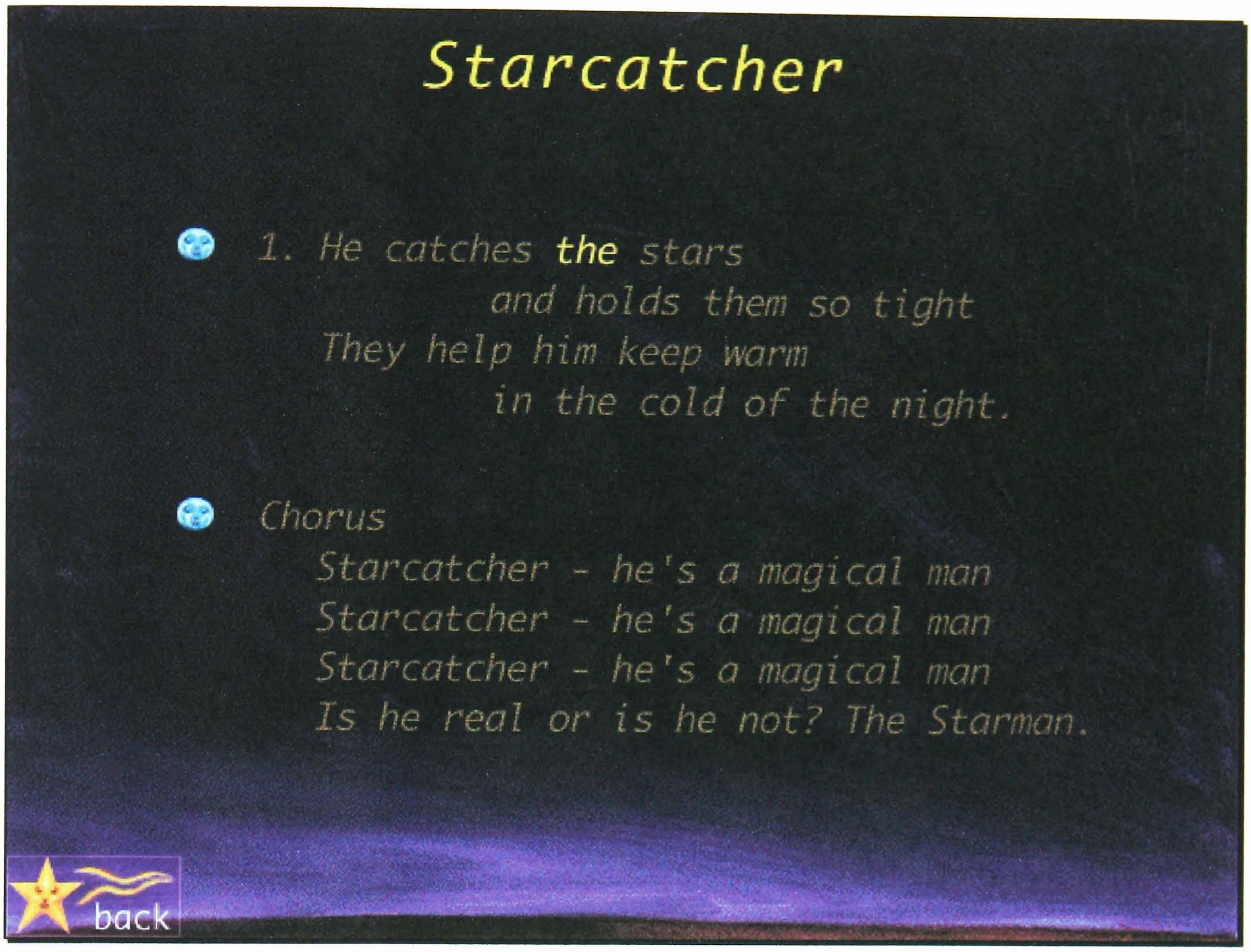


Figure 2.12: The interactive song screen.

The original intention was to make each word of the song sound when clicked on. The technique was technically possible but as the music also had to be halted while each word was heard, the effect might be confusing. The idea of revealing the text of the whole song was also rejected, because the words on the screen display were too small to read. This decision to only reveal a verse at a time coincided with the method used in the radio series where only one verse per episode was presented to children as part of their cumulative progression of learning the tune and words.

The proposal to use an animation to illustrate the theme of each line was rejected on technical grounds, because there was no space on the page for the animation to take place leaving an area of the screen clear for the highlighted text. Also overlapping layers of interactivity caused conflict in the software operation. On reflection, animation would certainly have detracted from the central activity. The first methodology pilot showed children were fully engaged just singing along with the highlighted words for the whole verse, enjoying the pleasure of the music, and remembering the words and were delighted in being able to repeat the music at their own bidding. The result was a simple layout in Figure 2.12 allowing children to choose the option of playing a tune line by line as well as a whole verse.

The sound file heard on entering the song page is 'Click the moons and see what happens.' The first methodology pilot suggested children would join in more quickly if the sound file was modified to i.e. 'Click on the moons, sing along to learn the words and tune.' The change was made. A page of words that appears too complex for young children to read in a conventional medium may now be manageable in an interactive environment because of the highlighting of individual words and because of the control children now have over repeating the words. Children sing along with the tunes themselves. What was immediately clear was that when 6-year-olds were asked to learn the words and join in they began singing and jigging up and down very excitedly.

2.3.4 The interactive story page

The interactive story page was designed to incorporate the story element integral to the radio programme. Each radio programme in the series contained one episode. The essence of the story was the quest for children in the story to find out who Starcatcher was through tales told by grandmother and a series of adventures.

Figure 2.13: The interactive story page.

Originally four speech bubbles were planned, one for each child in the story page illustrated in Figure 2.13 above, which on rollover appeared in text and in audio, 'Hello everyone', 'Hello Stella', 'Hello Sam', 'Yes, Gran, please', 'Can we hear a story please?' The decision to use sound files only was based on the complexity of making the speech bubbles appear and making the child icon images draggable at the same time.

The design of the page in Figure 2.13 demonstrates the application of principles informed by the literature survey (*see chapter 3, Improving learning using pseudo 3-D perspective interfaces, p. 117*) with the overall 3-D perspective effect, a viewpoint from above and the child icon images. They are intended to represent users being an integral part in the picture as well as their positioning to give an 'over the shoulder' viewpoint into the computer. The effect of making children able to drag 'themselves' into the picture achieved by slowly fading the figures as they are dragged to the doorway enhances the transition function of music and sound effects in storytelling.

Figure 2.14: Inside Granny's living room.

Figure 2.14 is the view revealed when all four figures have been 'dragged' into the house by users. The sound file plays 'Tell us a story Gran.' In the first pilot version the icons were not constrained, so children started to put the child icons on the roof of the house. They went off-task very quickly and this opportunity was dealt with by constraining the icons of the children to only 'go' through the door area.

Figure 2.15: The story animation page.

The original plan was to make a shadow of Starcatcher move and blot out stars of the story screen in Figure 2.15 above, as the story sound file played. Starcatcher is a male figure, an option to change gender could have been chosen, but the male reference in the radio series was maintained. Stars were to be moved about by users and then put in Starcatcher's pocket, which would then glow and the stars would stream out as shooting stars. Figure 2.15 was proposed to zoom into the centre screen from Granny's window space in Figure 2.14 giving the appearance of the child icon images being drawn into space (and the story), and dissolve into the night sky as the story sequence started. Due to pressure of time the animation was simplified in the final version of the Research Tool, so the stars disappear as Starcatcher moves across the screen and his net catches them. The researcher was surprised that the passive listening and watching the animation of the story screen appeared to retain its appeal, despite the expectation of children for there to be active participation thorough mouse clicks. The effect may be due to children listening and looking to good quality sound and visuals at close range. Certainly the experience would have been unusual at the time. In the second software trial there was a lot of discussion. 6 to 7-year-olds asked very excitedly if Starcatcher was real? The reaction may not seem surprising in reference to Beard (1972) drawing attention to Piaget's observations that children at this age imbue moving objects with life and will talk to the objects as if living things. This aspect was considered in the literature review *(see 3.3.5 Manipulation and conventional education theory, p. 96).*

In a primary classroom the value of 'useful noise' – educationally valid activities such as reading aloud, small group singing and discussion is well-established so a small group of three singing the song in a busy classroom would be acceptable and a teacher would accept a high sound level to retain attention against the normal high background noise of a classroom. At the time, headphones were not generally available due to the size of headphone connectors on computers. The pace of the story (unchanged from the radio version) was not a problem, only a pause between mouse click and audio file playing. The result of was children's discussion about 'Have I done something wrong?' The technical problem was solved in the final version by shortening the blank space before the audio story file began playing. The researcher's contextual research as to the ability of CD-ROMs to create feelings of anxiety caused by incorrect timing is demonstrable in this instance. The suspension of belief was dissipated by the inaccuracy of the pace, which can be defined as the acceptable pauses between phrases in narrative recording. In radio production terms pauses of longer than three seconds are not considered acceptable. Having solved this technical problem the Research Tool was made more effective allowing for the focus on the issue of the pseudo 3-D and manipulation aspects designed into the research methodology.

2.3.5 The activity pages

The decision as to the order in which the activities were listed initially depended on the sequence in the radio broadcast. The radio series contained an organised progressive plan of musical activities designed to develop music concepts. From the researcher's radio production experience it was common practice to avoid spelling out the educational aims (to children) in the broadcast. The focus of a broadcast was in its stimulating content. Too much didactic material had been shown from production experience to be counterproductive in radio terms for this age group. The opportunities for applying the educational message was clearly spelt out for in the teachers' notes. The result was that, as in the radio programme, the progression was not spelt out to users, though the coherence was inherent.

Activity 1

The original educational aim of this activity was to help children identify and familiarise themselves with the idea of a tune. The radio technique was to use the presenter to play the tune, repeat it and sing along and to clap hands. would repeat the activity as many times as required using the taped version of the programme.

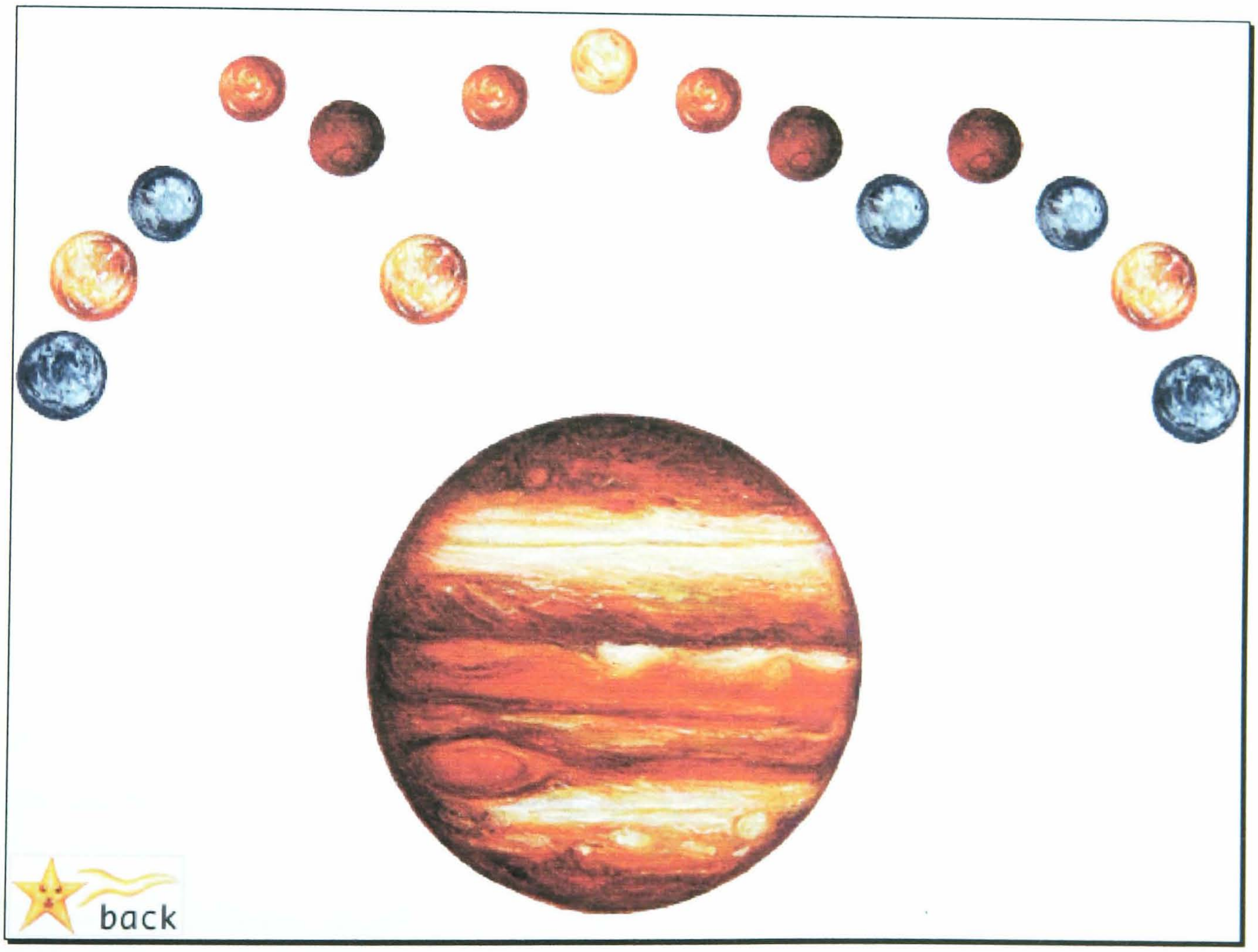


Figure 2.16: Activity 1 – Identifying a tune, Jupiter and moons.

The first draft computer design in *Figure 2.16* involved interaction which consisted only of the planets glowing in time to the 15 notes of Holst's Jupiter Planet Suite theme. The advantage of this feature was that it could be repeated as much as children required to 'get the point' without teacher involvement – repetition being the facility that teachers would have to mediate – because of the technical difficulty of accurately rewinding the tape and through pressure on their time.

The first development of the interactive design was to add a sound file demonstrating the tune pattern from the original radio programme. The second interactive development was to arrange Jupiter's moons through height and colour, a familiar graphic notation method in music education. The third development was to make the moons clickable icons and break up the sound file so each moon could be 'played' by children.

The audio instructions were changed to help manage the interactive process. The first version of the rollover instruction was 'Listen to this voice and then click on Jupiter' and then, 'Now click on Jupiter'. By adding a suggestion to 'click on the moons and play the tune yourself' so the educational value, through greater interaction might be increased considerably. In the last changes, the second element of the activity was locked until after the first element had been achieved. The result was to stop children accidentally going off-task by clicking on the small moon first.

The graphic image underwent several changes too. An early design draft illustrated the realistic rings around Jupiter, but this made the 'glows' of the moons difficult to see. On reflection the original idea was much too adult. The desirability of giving Jupiter a name label or referring to its size was also considered as children at this level cannot recognise the planet from its shape on the screen alone; but the change was not made because of the time constraints of the production process.

The music was chosen carefully. There were several attempts at choosing the exact length of the musical phrase. In the end a few bars in front and at the end of the main tune were selected to allow a lead in and place the musical pattern in its context. There were 15 beats in the music theme that would have left Jupiter (with its 14 moons), one beat short.

Luckily, during the period of work on this project another Jupiter moon was discovered by US satellite probe.

Some negative reactions by children about the version of the activity, as shown in Figure 2.16, were observed in the second software trial. Children found the adult's voice amusing and they did not know which of the symbols was Jupiter, but quickly guessed. These aspects were not changed because they did not adversely affect usage. However, the moons did not light up enough to give effective feedback in poor lighting conditions so the colours were given a richer hue.

In the final version of the activity the following sequence was established: audio instruction of what to do, audio demonstration, visual demonstration, invitation to copy the process; a technique used in radio music programme formats, but also an instruction technique central to primary school teachers' didactic methods. However, children were not asked to, or informed of, the possibility of creating their own tune from the sequence, but the software was capable of this deeper level of interaction. The considerations informing this decision were the length of the instructions for the age of users and secondly, the time available to code a second screen for the open-ended element. It was decided to be aware of the potential and look for children exploring the function in observations during the main study. There was a general intuitive feeling that the activity did not sit well at the beginning of this activity sequence. The decision was taken to put it at the end of the Activity list in position 6.

Activity 2

To give the most space in this interactive screen for the pockets, the top of the head and the feet of the graphic were ignored. Children had to click and drag four stars in the boy's pockets to hear the word 'star' four times in rhythm pattern as the icons glow in the four pockets. The four star icons in Figure 2.17a then turn in to four shining star icons to be put in to the pockets and, on completion, turn in to four shooting star icons.

Figure 2.17a: Activity 2 – Familiarisation with music pattern using star words.

Audio files of 'star', and 'shining star' and 'shooting star' were taken from the section of the radio programme, illustrating the theme of the song but also the pattern of beats of music using syllables in the words.

The entry frame audio instructions are 'Put the stars in the pockets and hear a musical pattern.' It was thought that adding to this phrase 'Join in and clap your hands' would encourage children to sing and clap themselves, so the exercise might be more educationally effective by physical involvement giving greater depth of engagement.

The distance that children are required to drag the stars was found to be too great for small hands. This appeared to be caused by the difficulty or lack of experience of lifting the mouse off the mat to reposition it, and also the length of the 'dragging' distance across the mouse mat. The solution was to make the longest distance of drag half the width of a standard mat as in Figure 2.17b.

Figure 2.17b: Stars repositioned for easier manipulation.

Activity 3

The task in the radio broadcast is for children to learn about the structure of musical notes using the syllable pattern of words as examples. In the interactive version they choose from planets with different numbers of syllables. Dragging them into the pockets causes the sound files to play, for example Ju-pi-ter, and shoo-ting-star. The entry frame audio instruction was originally 'Put the pictures in the pockets and hear them play. Hear them play a pattern.'

Originally ten pockets were proposed based on the number of syllable pattern examples in the radio programmes. However, the number was considered to confuse children with too many choices in a new media context, and so the number was reduced to 5 as in Figure

2.18 as a compromise between the available space on the screen and the size of the icon for children to manipulate using the click an drag issue discovered in activity 2. Each icon has a sound file of its name attached. When the pockets are all full the whole sequence plays the spoken words stressing the syllables: Ju-pi-ter, star, shoo-ting-stars etc. Children can repeat the task as many times as they like.

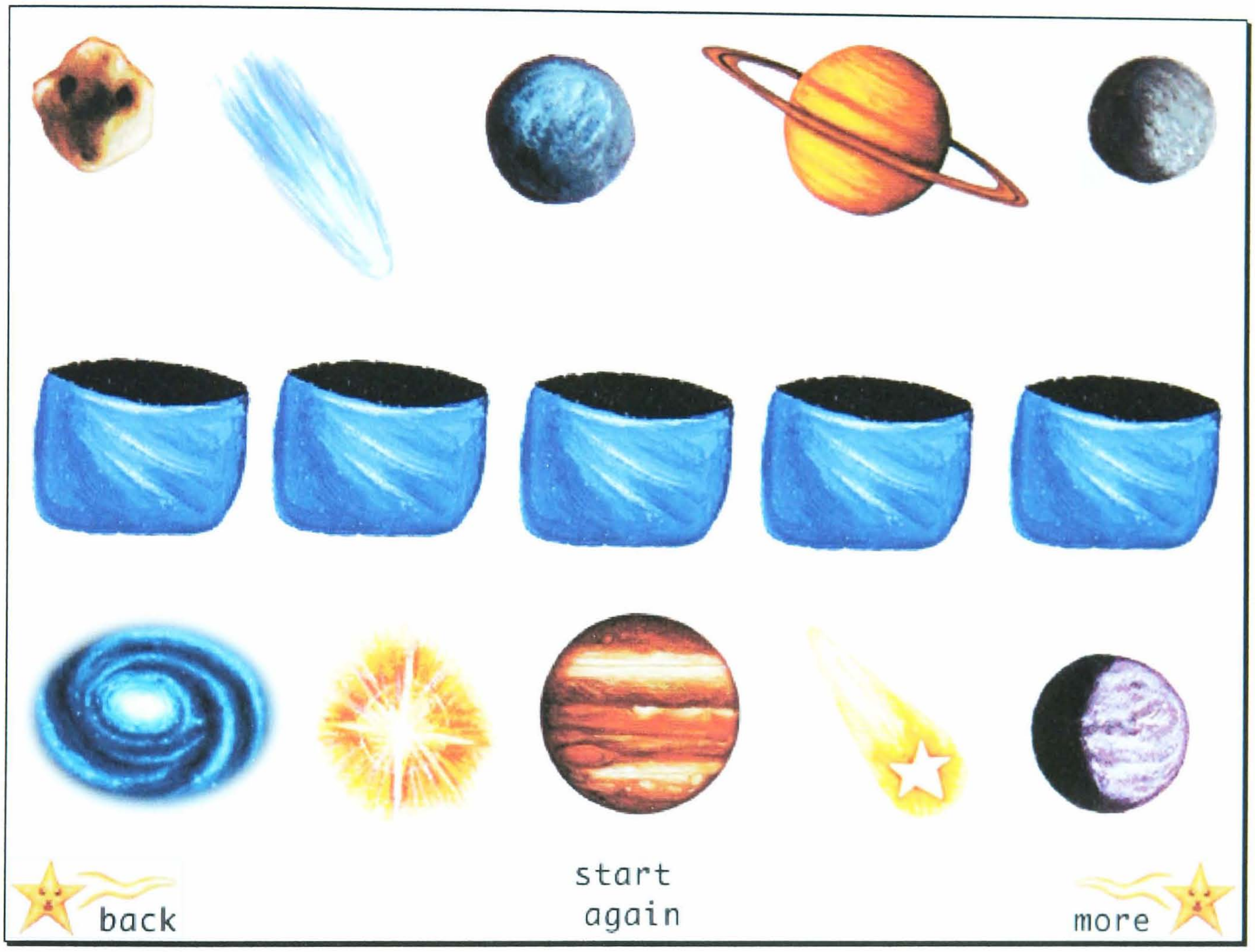


Figure 2.18: Activity 3 – Space words patterns. Pocket icons in the middle row and ten space feature icons such as asteroid, comet and Jupiter on the top and bottom line.

The order of the pockets can be changed too, one or more pockets at a time and the new sequence automatically starts to play again. The addition of the change in order option was not flagged in a sound file instruction at first and was added later for the main study. The words were also changed to make the potential clearer: 'Put more space pictures in more pockets. Say the words and clap your hands in time. After that clap your hands and chant your new star word pattern.'

Activity 4

The layout of the screen is exactly replicated from the pupil's booklet for the radio series in which children were asked to write the correct words in the correct boxes. In the computer interactive version illustrated in Figure 2.19a children click and drag letters and order them correctly in the box below.

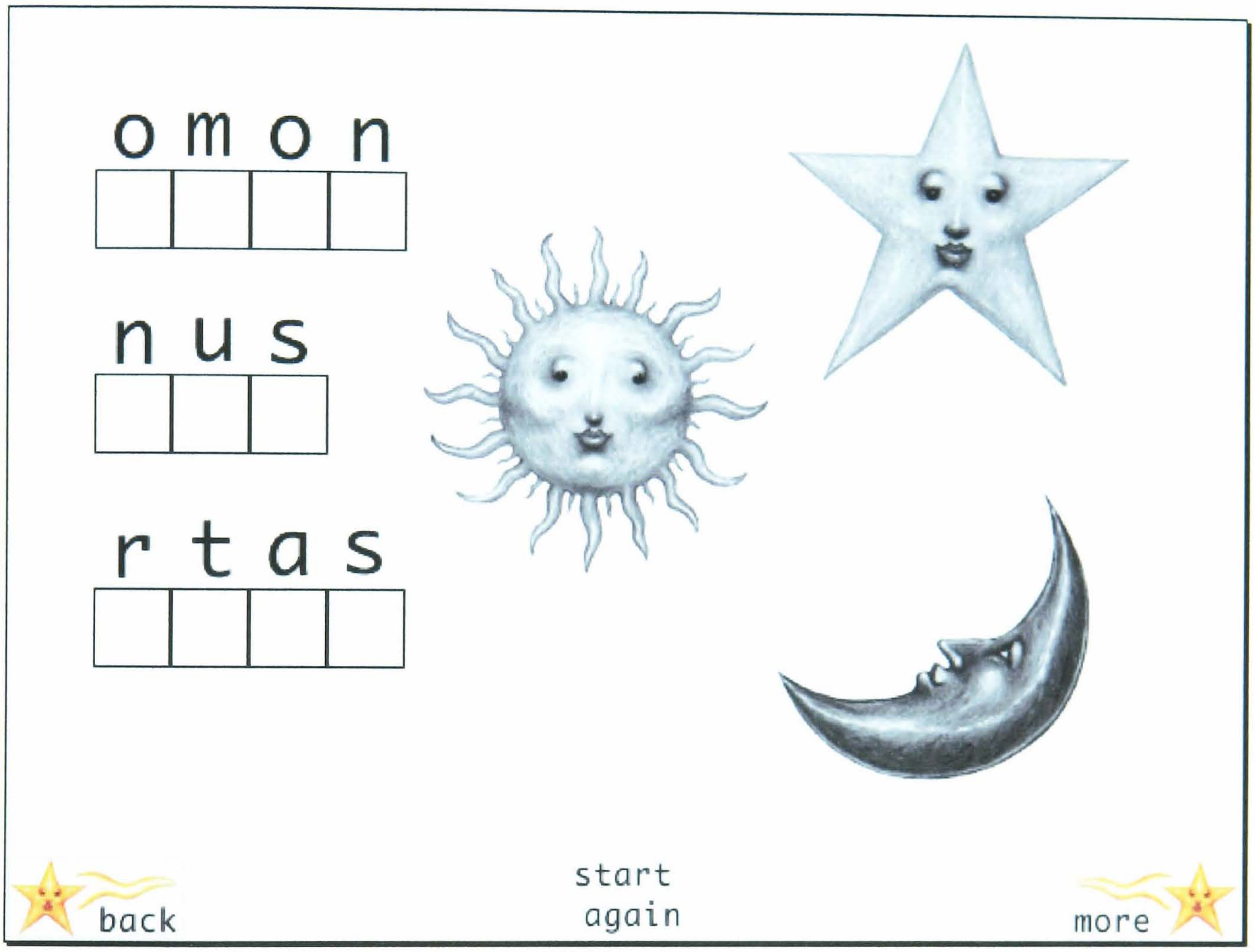


Figure 2.19a: Activity 4 – Spell the words and match them to the pictures, star moon sun.

If they make a spelling mistake the letters jump out. When the spelling is correct the matching symbols change colour and move. Children can repeat these activities as much as they like. The entry frame sound file is: 'Spell the words and see what happens!'

The researcher observed in the first methodology trial that children did not notice the moon rotating when they spelt 'moon' correctly. The reason was thought to be that the moon was too far away from the area of focussed attention – an observation that could be accounted for by the tendency for young viewers to engage in visual fixations as identified by Bruner and Mackworth (1970) – and described in detail in chapter 3 *(3.3.2 Children's eye function, field of view, and vision issues, p. 76)*. The decision was made to apply Bruner and Mackworth's observations by making the spatial relationship between mouse activity and animation much closer. Bruner and Mackworth's findings and the existence of the 'foveal oval' of attention are discussed in more detail in the literature review. In addition the size of the area of each letter was observed to be too small for children to easily click and hold with accuracy. The letters and boxes were therefore enlarged. The solution is indicated in Figure 2.19b.

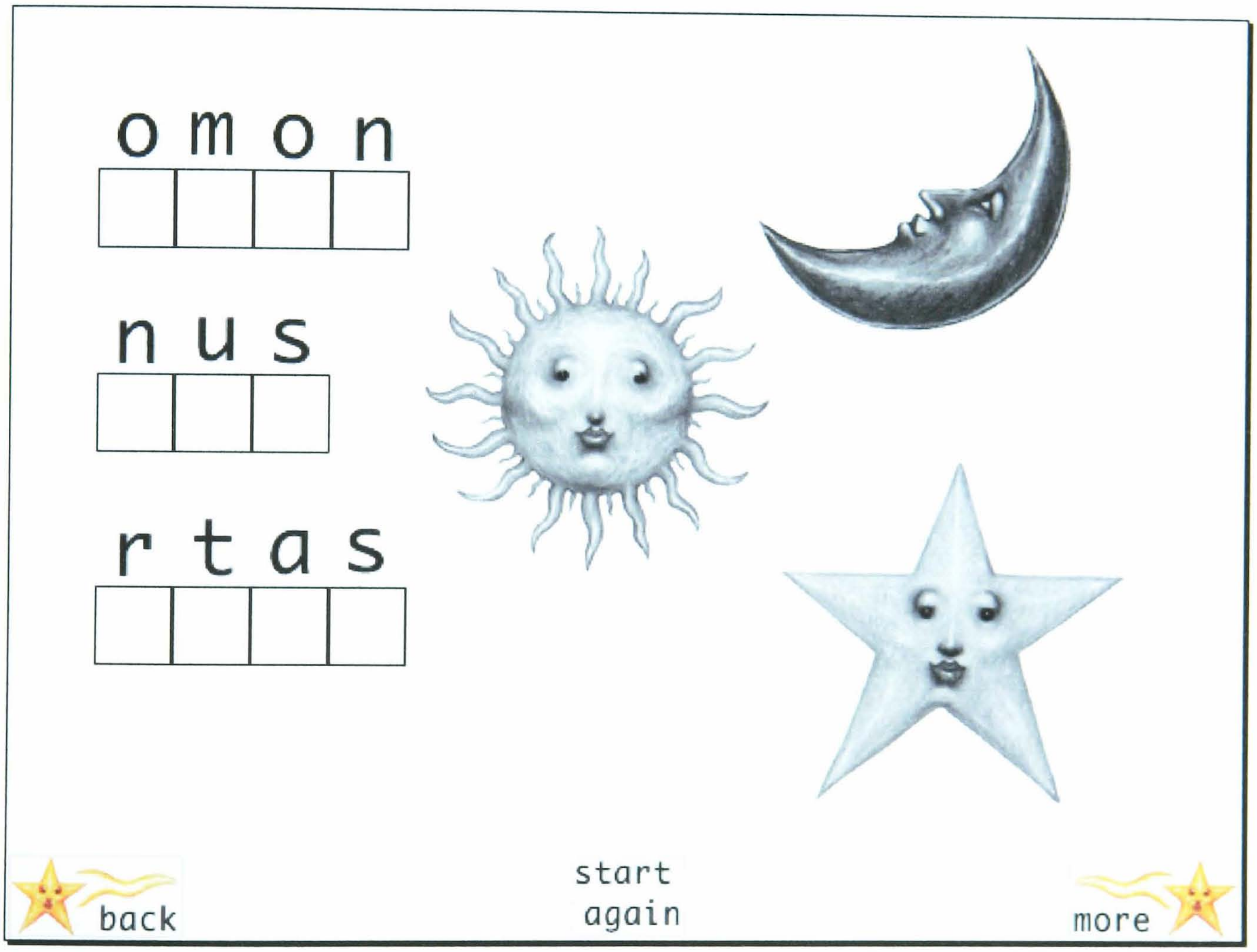


Figure 2.19b: Revised version of Activity 4 with icons rearranged for easier visual recognition.

Activity 5

In the activity illustrated in Figure 2.20 the entry frame sound instruction asks children to: 'Choose your favourite sound for each space picture. Use your beater and play a space rhythm'. Children click and drag the icons to the symbol.

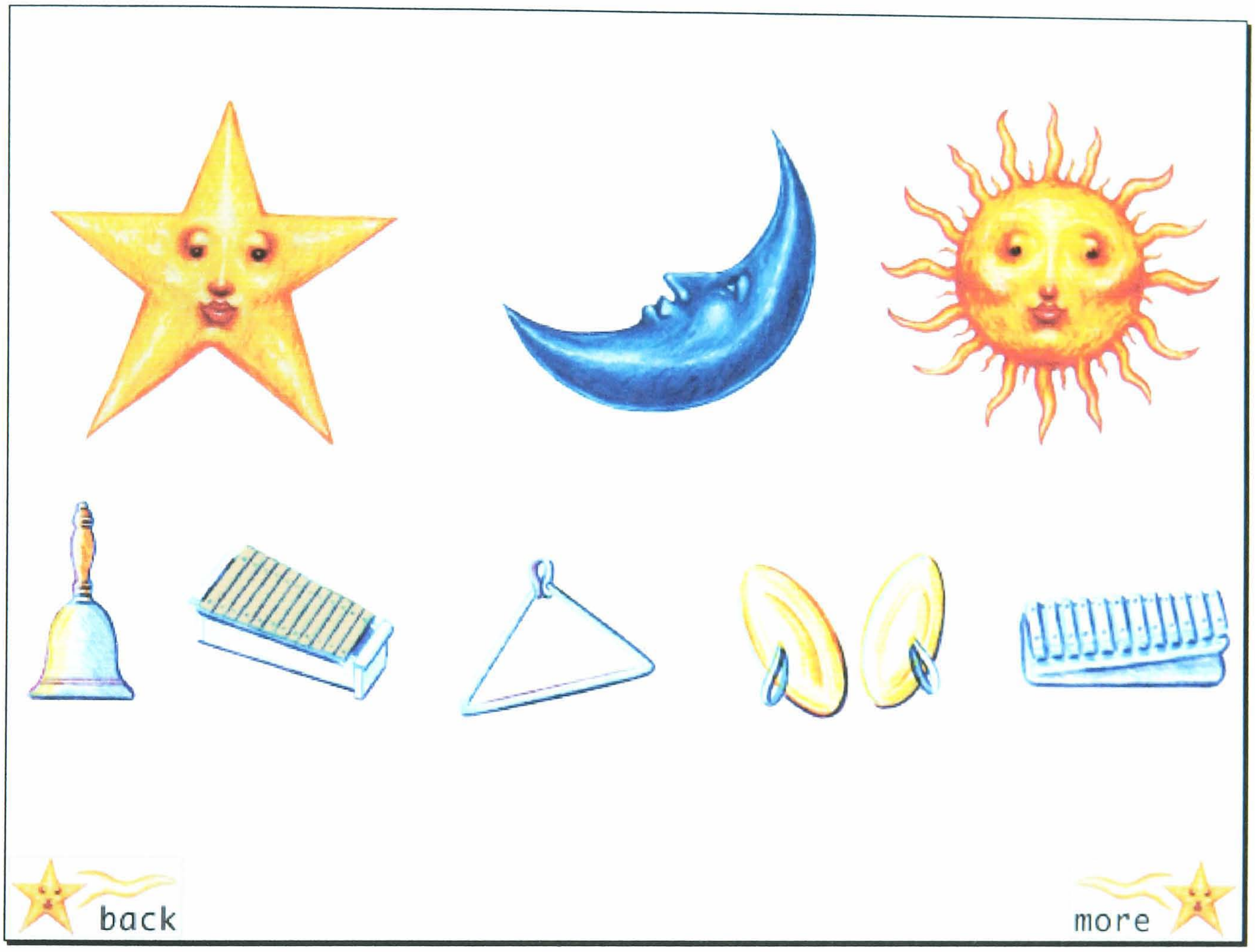


Figure 2. 20: Activity 5 – Choose an instrument sound for each picture, star moon sun.

The instrument then disappears and a beater appears instead of the arrow icon which, on a mouse click, plays the instrument sound. The activity worked very well during the early trial and no changes were made. In the radio broadcast children are asked to choose star-sounding percussion instruments and creating appropriate 'starry' sounds with real instruments after the programme finishes.

Activity 6

The activity was originally an activity described in the teachers' follow up notes – for work after the programme had ended. It is a class activity using real percussion instruments, and represents 'progression', an increasing of children's understanding by extending experience by stages. In this case 'progression' is based on the previous exercise.

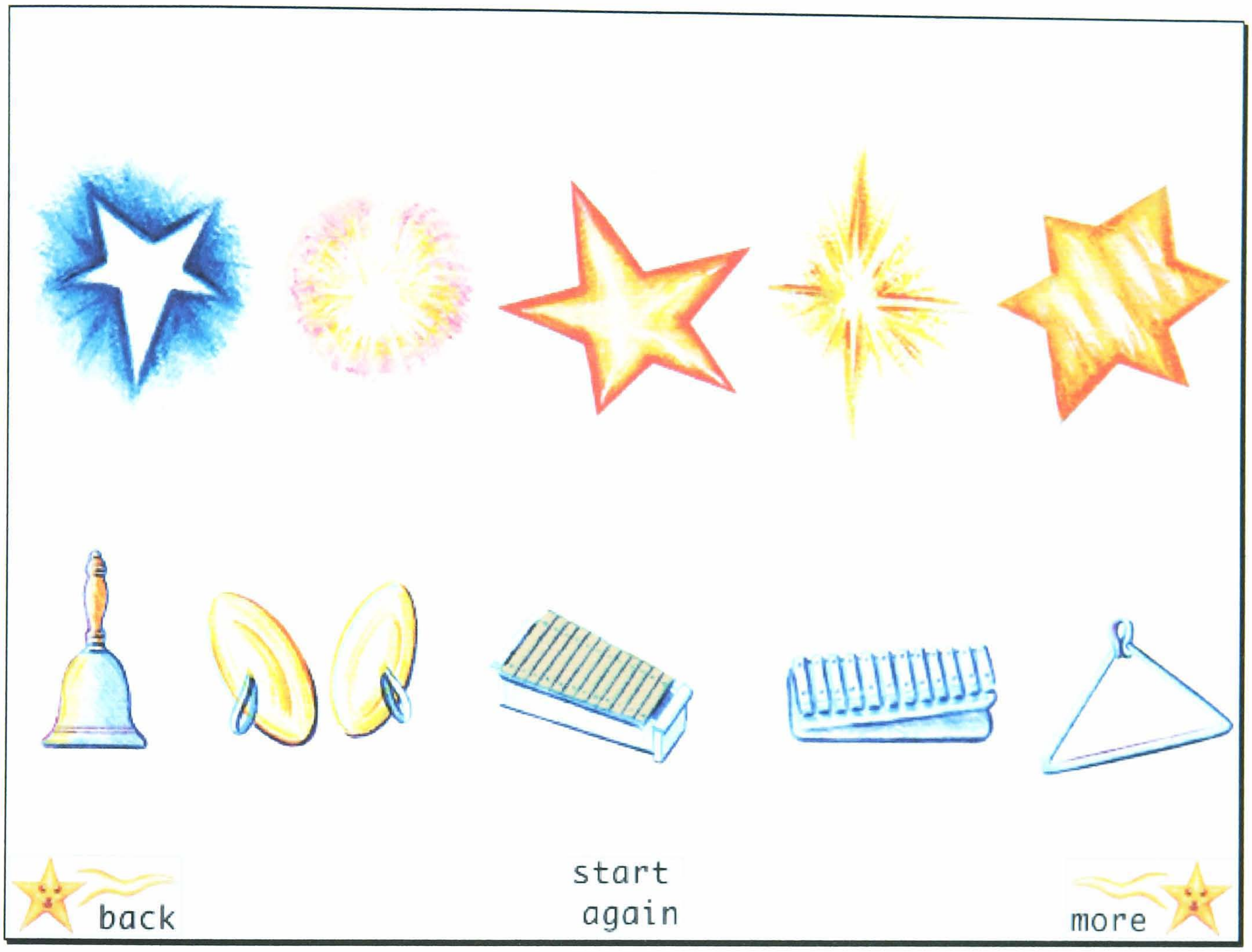


Figure 2.21: Activity 6 – Choose a music sound for different stars. 5 stars, each with different instrument sounds.

Children move to a further level of abstraction relating musical sounds to similar versions of one star symbol. In the interactive version illustrated in Figure 2. 21, the audio instruction asked children to: 'Move the pictures around to make a sound pattern. If you want, choose a new sound. Play your pattern to a friend.' They can click and drag the 5 icons to different star shapes. The music icon disappeared and when all the stars are 'filled' the sequence plays. When the musical icons changed, the whole sequence plays again, but the sequence cannot be stopped during the play sequence. The order of the stars can only be changed afterwards and then the new order played. This activity created an unexpected amount of discussion in the early trial, not so much on which instrument to choose for a star, but because the instrument could not be seen after it had been chosen, but the discussions were about 'which sound had gone where'. The activity seemed to become a memory exercise. There was no programming time to develop the concept further or make changes. It was recorded that adding small instrument icons by each star when it had been placed would probably have lessened the memory load.

The decision not to delete this activity was made on the basis of exploring whether children are drawn into or reject the activity because of the memory task. They are solving a problem and being required to relate a symbol to a sound in memory. The final reordered list of interfaces is summarised here for clarity.

The Opening screen:
Users choose icons representing 'stories', 'songs', 'things to do' (activities).

Activity 1: Users click and drag letter icons to spell 'star', 'moon', 'sun'.

Activity 2: Users put icons in to a boy's pockets.

Activity 3: Users put planet icons in to a series of pockets to make a rhythmic pattern.

Activity 4: Users create star tunes choosing an instrument for each star, moon and sun picture.

Activity 5: Users choose a music sound for different stars – 5 stars each with different instrument sounds.

Activity 6: Users recreate the Holst's 'Jupiter' tune and their own tune using the same notes.

Story: The animated first episode of the 12 stories of Starcatcher.

Song: Users hear and sing along with one of the many songs from the radio series.

Teachers' Control Panel: The 7 stars on the opening screen that switch on or off items from each list of 7 control lists.

2.4 Summary

The chapter has recorded the refining of the Research Tool design in detail. The design originally focussed attention on the three areas: the need for an interface for teachers; recognition of eye physiology and children's visual ability issues; and the potential of a pseudo 3-D storytelling interface. In addition during the development period there were discoveries that:

- The use of audio instructions gave added flexibility for children to use the Research Tool without having to read or to depend on teacher involvement.
- The role of manipulation of objects using the mouse has potentially greater depth of engagement than clicking with the mouse and also greater educational value.
- The order of activities should be changed.
- The activities prompted discussion amongst children.

The Research Tool achieved the original plan to be a teacher-controlled product and the changes were incorporated so that it functioned effectively. As indicated in the cross-referencing the following areas are subject to further study in the literature review.

- The apparent ability to program physical manipulation of objects achieving a deeper level of engagement encouraged in-depth research into manipulation and flow theory and a resonance in conventional education theory.
- The role of the navigation metaphor.
- Inconsistencies in the holistic approach of ergonomics and human factors.

The chapter has been an account of the production of the Research Tool. In the literature review in chapter 3, the Research Tool is first put in its historical context by a chronological account of developments in educational information technology up to its inception and second, the areas of enquiry that arose as significant elements in the production process are described in greater depth.

Chapter 3: The literature review

3.1 Introduction

Chapter three is a study of the literature that informs the design of the Research Tool and defines the areas of enquiry for the main study. The literature review and the Research Tool production took place in parallel because the BBC required that production should be completed by January 1995. The chapter is comprised of two sections. The first section, *3.2 IT in primary education* is a review of texts concerning historical events during the development of Information Technology in primary education. The aim of this section is to ensure that the Research Tool is placed in the context of these developments and reveal the lack of research which has resulted in some issues being overlooked. For example, the section indicates the lack of research into close observation of what children are doing when they use computers in the classroom environment. The Research Tool was designed to rectify the situation. For example, difficulty observed by children caused by unstructured organisation in the early multimedia software investigated has led to the incorporation of a teachers' control panel menu system allowing teachers close control of the Research Tool in the classroom.

The second section of the literature review, *3.3 Interface design* redresses the evident lack of research into what children do when they use the computer arising from the review in *3.2 IT in primary education.* The areas of research are summarised in detail and the beginning of that section – issues that the researcher first raised in his close observations of children using computers – form the structure for the review. The contextual research described in chapter 1 *(p. 9)* for example children appeared to ignore icons in the corners of the screen and the physical problems of children managing the mouse are included for clarity and then investigated in detail in the review that follows. Aspects covered in section one of the literature review are now outlined in more detail.

The preliminary observations of the research in progress were published in the British Journal of Educational Technology in April 1997 (*See Appendix 2*).

3.2 IT in primary education

The section IT in primary education is a critical analysis of the significant historical events in the development and growth of the introduction of information technology in British Schools. A definition of information technology (IT) precedes a discussion of early approaches to software and is followed by an overview of IT education research during this period.

- The period of the survey is from the early 1980s to the late 1990s, the first major introduction of computers in schools.
- IT developments are investigated in chronological order using examples of software, particularly in the UK.
- It is a survey of these events and focuses on the lack of well-organised research into the use of IT in classrooms or the effectiveness of policy introducing educational IT software into schools before and after the National Curriculum in 1989.
- The National Curriculum is identified and referred to as the watershed, dividing the two periods.
- Central to this critical discussion is the lack of research into the use of IT in the early period of implementation and that in the latter period the research was constrained by 'hardware first policies' and organisational problems around traditional pattern of administrative methods such as the1982 Micros in Schools Scheme.

Information technology, in an educational context emerged from a general exploration of using computers to aid learning in the 1980s. By the 1990s IT was clearly defined to be, 'The development of pupils' capability to use information sources and IT tools such as computer systems and software to analyse, process and present information, and to model measure and control external events.' (DfEE, 1995, p. 1)

The IT activities at the beginning of the research period (the 1980s) involved children in individual, group or class experiences. However, the consensus on what can or ought to be taught as IT has changed over time. For example, Nicholls and Richardson (1995) suggest IT was associated with the use of computers for instruction, and expressed reservations about their application in an educational context. They hoped the aim of IT was to aid investigation and discovery through practical experience. They stressed the need for developing essential skills such as observing, checking, applying ideas, classifying or evaluating with second-hand experiences. Attention then shifted to a discussion concerning the relative values of the role of information technology as a source of skill development and the application of the technology in discrete subject areas (Andrews, 1996).

The definition of Information and Communications Technology (ICT) is a more recent acronym replacing the use of IT. The focus of ICT includes information technology that supports teachers in their everyday classroom across every subject, but also in their training and development in administration. The technology includes not just the Internet, CD-ROM and other software but, television and radio, video, cameras and other equipment (DfEE, 1998).

In the next section three early trends in the development of IT are identified and discussed to show the evolution of styles of Information Technology developments.

3.2.1 Logo, CAL and simulations: three trends in early IT development in schools

This section investigated Logo, Computer Assisted Learning and simulations, three particular aspects of early innovation in computer software in schools. The introduction of Logo in schools illustrated the pattern of educational research in the 1980s before the centralisation of the National Curriculum – exploratory, practical classroom experience of IT – valued by teachers when the software could be adapted to the reality of the classroom, a ‘bottom-up’ approach to the introduction of IT. However, it was suggested that Logo has not achieved its original ‘top-down’ goal – to teach mathematical concepts through programming – certainly not in the primary school.

Logo

A survey of the introduction of Logo into schools was important primarily because in the 1980s when IT was in its infancy there was generally little software created and few programming languages in use. Logo stands out in the history of IT because there was no other programming language at the time appropriate for the purpose. The Beginners All Purpose Symbolic Instruction Code (BASIC) software language was considered to be too complicated for children to program by Hoyles et al., (1985), who also suggested a significant strand of educational thought in the 1980s – that children should be taught programming. Learning about computers – would provide another educational benefit that programs could be written by committed teachers. Indeed Logo was a common topic written about in popular magazines, a pattern only recently revived with the simplicity of HTML web coding.

In Britain in the early 1980s attempts were made to use Logo as a support tool to teach mathematics. There is a case for showing that the enthusiasm for Logo by British educationalists was misplaced and unfortunately influenced by the US example. British research (Hoyles *et al.*, 1985) showed that Logo could not teach mathematics in its broadest sense as seemed to have been shown in the US.

Papert, the developer of Logo focused on the use of programming languages to teach mathematical concepts, (Feurzig, 1969). Papert (1980) then developed this theme into an influential book called Mindstorms. He invoked connections with Piaget and stressed a significant role for computers in learning for a changing society. Whilst the opportunity to introduce children to computing skills became a popular theme in magazines, Solomon (1982) and Ross and Howe (1981) criticised the close controlled conditions of the Logo testing in American schools as being artificial. The longest running research into Logo in the United Kingdom was at Edinburgh University at the Department of Artificial Intelligence (1976 onwards). This involved children over eleven. The concerns were wide ranging, but purported to examine the value of Logo to teach mathematical concepts. Many of the studies involved children learning to program using worksheets, and studies also covered metaphors for the computer process. One of the results was that programming became an end in itself not a means to an end (Goodyear, 1984, p. 166). Conclusive proof as to whether the mathematical ability had improved was not confirmed, but the improved articulacy in mathematical discussion was noted as was the pupil's ability to communicate sensibly and clearly about mathematics.

At the time, teachers looking at these reports might assume that using Logo could give their pupils these benefits and justify them in trying it out. Also Logo had the support of the London University Institute of Education where a study had been carried out looking at what the Americans had done and researched its value in the context of British schools. It was a small-scale study by Hoyles et al., (1985) that examined the impact of Logo on mathematics teaching on 7 pairs of children, mainly secondary with some primary children. The study revealed that:

> Pupils don't follow stages of planning hands on and debugging in sequential order when working towards well-defined goals (Hoyles *et al.*, 1985, p. 272).

The report found no evidence of the value of Logo for developing problem solving strategies and the nature and extent of the collaboration between students. Yet programming activity was claimed to be a powerful aid to decentration (the reflection on one's own thought processes). There was no evidence for the claim that Logo gave teachers a transparent indication of how children perceive a mathematical problem and formulate its solution. The report mentioned the long sessions required getting the most out of Logo. 'The product design was not changed to take into account this real classroom limitation.' (Hoyles *et al.*, 1985, p. 1)

One of several studies looking at the use of Logo in primary schools was The Chiltern Logo project, which began in 1982 (Noss and MEP, 1984b). It highlighted the unreality of comparisons with the American experience where there were large numbers of computers available in specialised rooms. The study focused more on the problems of time and the requirement for young children to immerse themselves to the detriment of other areas of the curriculum. The original aims of Logo for mathematics became more loosely interpreted as skills in planning, hypothesis testing and problem solving.

An indication of the fervour for programming at the time was provided by Goodyear (1984) who rejected the testing of Logo by measuring its capacity to be cosily integrated into the established classroom 'as nonsense.' He wanted to establish whether Logo could embrace exploratory child-centred conjectural learning. Noss (1984c) suggested Logo was more acceptable in primary schools because of the flexibility of the timetable, even when the project schools had one dedicated computer per class. Noss found children's problem solving skills developed considerably as their knowledge of Logo increased.

The Chiltern Project explored the value of Logo as a generic program. Its aim was to reinforce the concept that children should be in control of machines rather than being 'programmed' by them. It claimed that Logo provided advantages for education compared to using the computer for word processing, environmental and topic work. Yet Taylor (1980) suggested Logo has a tutee role and that the Logo program was not open ended. Wellington (1985) suggested that Papert's claims that Logo changes the nature of the learning environment are largely unjustified and that children found programming difficult. Adams (1987, p.1) saw the main issue to be the 'little chance of widespread acceptance against the prevailing conservatism of computer science educators'.

However, the MEP strategy encouraged building on existing curriculum projects such as The Chiltern Logo Project and the endorsement may have given Logo legitimacy at a time when there was a mushrooming of interest in computers, especially when there was a lack of commercial education software available, (DES, 1987). It was also a time when programming was relatively simple and many individuals were programming using Logo themselves.

Goodyear (1984) confirmed this picture of Logo's development. It was a period clearly described in his introductory chapter. It was a time of exploration, of lack of software, of concern to make the best use of the new technology to provide support for uncertain and worried teachers. However, only the most enthusiastic and competent programmer or teacher could understand any of the programming necessary to carry out the classroom activities in the rest of the publication. Noss (1984b) admitted that Logo provided no evidence of a positive effect on children's learning of programming skills. He suggested that programming gave children power over the machine and there was value in the incidental learning that took place while learning to program in Logo. Hoyles et al., (1988) also confirmed that 'despite the many years of research in this area there is as yet no firm evidence that there is any transference of skills from programming in Logo to problem solving in other domains' (p. 108). The difficulty of defining what exactly was of value in Logo may have been due to the poor quality of research. Maddux (1993) asserted that the popular view of research into Logo is contradictory because researchers ignored learning and teaching variables and interactions.

However, today Logo is still being learnt as a valuable experience in problem solving (Kapa, 1999). Logo is also being used for simple exercises in control, but only two of the simplest ideas in Kapa's book have endured. These are first, control programming for the on-screen and floor turtle and a very important second, the development of mathematical concepts through the creation of patterns. These are seen as simple, enjoyable and educationally justifiable projects. This is how teachers are using Logo in many primary schools today and is included in the National Curriculum. It is important to note that children achieve these tasks by writing the simplest code using Logo programs that other people have written in the early stages of development (Forster, 1986). However, the enduring quality of Logo is that teachers can identify its value to children. For children readily experiencing 'a sense of owning' was powerful and more important than the idea of discovery as originally reported by Noss (1984a).

The researcher considered that the story of the introduction of Logo in schools illustrated the pattern of educational research during the period. This was the 'bottom-up' evidence that teachers' experience of Logo – their research over the years – recognised that Logo had some place in the classroom. It could be of value if teachers adapted the software to the reality of the classroom. However, the evidence was that Logo had not achieved its original 'top-down' goal – to teach mathematical concepts through programming – certainly not in the primary school.

Computer-Assisted Learning

In this section the example of computer-assisted learning further demonstrated the changing ground of IT during the period of this study. Computer-assisted learning in the United Kingdom was mainly a term discussed in a university environment. This section reviewed how software development grew in complexity but was overtaken by commercially available multimedia software tools. Primary schools were creating teaching material with different features to CAL designs which were predominantly drill and practice routines exploring the potential for independent or guided learning. The story of CAL development was of the creation of home-made materials specifically designed by lecturers. It was a university-based phenomenon with staff creating their own programs and using them for internal teaching purposes; a main theme of papers in the Conference on Computer-Assisted Learning Bristol, 1983 (CAL 83).

The feature of development of CAL methods was the attempt to computerise learning as an interactive process as opposed to typical early programs which involved users in making responses to lists and test questions of the drill and practice type. The model was the university lecture passive style of interaction. There was no definition of the quality of interface interaction. The model focused on the need to effectively track what students had completed and provide feedback. To support this view Tait (1984) described a typical example of the early stages of learning software design in the General Author Language Teaching System (GALTS) used by lecturers in Leeds University (p. 16). Authoring languages were first designed to make materials for learning using multiple choice questions. Learner Controlled Modules (LCM) were also developed to help students solve problems through a process of step by step solutions using a review and summary approach. Leeds University developed its own Frame Orientated Author Language (FOAL) creating frames – rectangular areas of the screen text – to be displayed in such frames and linked to interaction during the final compilation process. The system allowed users to phrase questions. The aim was to create an adaptive system to measure and anticipate the learner's needs and deliver sequences accordingly.

The narrow view of the early university-developed learning materials was identified by Elsom-Cook and O'Malley (1989) who defined traditional CAL systems as author generated materials presented by the computer which 'simply follows explicit instructions of the author in interacting with the student' (p. 69). But by 1990 an Open University team had developed a more flexible system called Enhanced Computer Assisted Learning (ECAL) which allowed an author (lecturer) to track student progress, and modify teaching materials.

The key element in the evolution and redefining of CAL that has endured was described by White (1994) who suggested that the source of the pressure for hypermedia was in higher education. 'We are faced with increasing student numbers, worsening student to staff ratio, and a widening of the ability range' (p. 64). Significantly White mentioned the first commercially available bundling of tools to create learning materials called HyperCard using the HyperTalk programming language which was developed by Apple Computers for creating what became known as hypermedia. White considered a strength of an open hypermedia system such as Microcosm – against a conventional authoring system – that there was no idea of developing a finite piece of courseware. The advantage of Microcosm was that the links were created as a linked database, the 'Linkbase' that sat behind all the documents. It could be rearranged so novice students created their own hypermedia links and even their own dissertations. The significance of HyperTalk programming was that while the discrete elements of authoring packages were expensively developed by universities for their own needs, authoring packages were becoming commercially available to everyone wanting to create educational materials through cheap, easier to use multi-functional authoring packages on the open market such as HyperCard.

Allinson and Hammond (1990) identified the programmed learning, intelligent tutoring systems and learner support environment styles of CAL, but pointed to the limitations of university CAL programmed learning which ignored the involvement of the learners being taught. The application in CAL programs of Skinner's (1968) theory of learning, that posits learning is reinforced through the process of operating a machine in such a way to get the answers correct in a mechanised drill and practice context was questioned by Allinson and Hammond. They suggested Skinner's theory of learning informed the approach to computer-based package design 'but to limit the learner merely, say, to browsing an information database, or to directed step-by-step tutorial, hardly matches the richness of everyday learning' (p. 137). The latter part of the paper was a consideration of the problems of disorientation with hypertext. This paper was significant because it reflects how commercial software forces overtook CAL development in Higher Education.

CAL had limited impact in the primary and secondary education sector. Freeman (1989) in a paper, perhaps one of the first CAL papers with 'multimedia' in its title, in the context of the higher education dominated CAL conference talked about multimedia developments in primary and secondary education being:

> ...a growth industry in production of multimedia materials for training, information and to a lesser extent education. The fruits of this industry have now impinged on schools, in the same way as other business software, such as spreadsheets, is making its way into schools. This is not surprising, as the major producers of software have had funding curtailed by the government since the demise of the Microelectronics Education Programme. (p. 189)

Freeman described navigating, discussed spatial awareness of maps and the interrogation of charts, data, pictures, text, in the BBC's Doomsday Project computer controlled laser disc system. Freeman observed how users reacted to the system by understanding how to use it and finding their way round. But she criticises the quality of the interactivity. Interactivity becomes consumed by dealing with problems created by the interface, not with the information, because of interface design difficulties (p. 192).

University staff looked to the growth in children's commercial software games to resolve the problems of poor quality presentation and boredom of university students using CAL. Wishart (1990) studied primary school user involvement with computers and their effect upon learning. The study involved an educational computing game called VESTA, a game to teach children how to avoid being trapped in a fire. The conclusion was that learning significantly increased by giving a learner control of action by increasing the complexity of the game progressively and providing challenge by using a scoring system (p. 149).

Watson delivered an early paper on primary school software at CAL 83 and suggested simulations improved group dynamics, discussion, and the interplay of ideas.

> an increasing number of CAL units in the humanities are not asking questions on the screen, but creating an environment in which the pupils ask the questions for themselves deciding a path to follow and seeing the impact of their decision on the screen. (Watson, 1984, p. 13)

What were the reasons why the university CAL experience was different to developments in schools? First, primary software programs were written by educationalists with practical experience of the primary classroom. Second, the software was free or very cheap using the BBC Micro. The ethos of providing shareware and grass-roots development of programs like the Microelectronics Education Programme was the norm. Third, the early work was carried out by teachers who created programs like Granny's Garden which were ready prepared for the market by commercial companies. CAL had little impact on primary schools.

However, while universities were embracing open and distance learning using the Internet at lightening speed, only recently has computer-assisted learning called Integrated Learning Systems (ILS) in a DfEE funded project re-emerged in the primary sector. In a report (NCET, 1994c, p. 14) of two US English and Maths products, the evaluation appeared to mirror the research evidence into the value of Microsoft's Windows software criticised by Maddux (1993). There was a list of concerns such as the quality of content, rate of progress and progression of ILS material. Also significant were the concerns over comfort, headphones, blinds and heights of the computer. There were comments about fall-off of concentration after 17 minutes, 15 minutes being the average. Primary students seem to show a deterioration of behaviour from their normal school level in the session immediately following an ILS period. One school solved this by a 5-minute session in the playground afterwards. Findings suggested it was beneficial to have a non-book-based activity after the period in the ILS classroom.

The long 'list of concerns' hindered the introduction of further computer software research. Education research was at an early stage and priorities were different anyway. Indeed NCET's priority was to manage and develop materials, research came later (Brown and Howlett, 1994) and the report expressed doubt that there would ever be the funds to provide the hugely expensive servers, systems manager, and dedicated rooms that ILS required in the UK.

The next section looks at the special role that simulations occupied in the 1980s and their disappearance as an educational tool in the 1990s. The researcher was involved in the early development of simulations, reflects on their value despite a recent decline in educational use, and considers principles that might be applied in the Research Tool.

Simulation

The popular definition of computer games covers a range of types of which simulation is only one, race games, arcade games being others. In an education context the role of computer games was specialised with specific differentiations concerned with their educational value. Tagg (1985) in a publication for educationalists and parents identified a list of different categories of simulations in schools, which demonstrated how early the genre had taken hold and how extensive was its exploration. The list was as follows:

1) Adventure games in which children take on roles. A typical example is Sending a Dragon Asleep in which children are encouraged to discuss each move carefully and only act when the group agree what to do.
2) Simulations – flying a jumbo jet around the world.
3) Programming turtle – Control and measurement BBC Buggy, making a creature move around, replicating a real world process.

4) Investigations: problem solving – a group of children uses an open ended program drawing polygons, creating a hypothesis.
5) Information Handling: Using BirdSpy to watch birds and log their arrivals using Quest to find dominant species.
6) Story Writing – based on simulations like Granny's Garden in which children have to rescue the imprisoned royal children, passing through various levels, by providing necessary information to get on to the next level.

Bradbeer (1982) evidenced that children liked using simulations, and encouraged learning without the mediation of a teacher. A simulation such as Mary Rose included one or more of the categories above by allowing children not just to search for a wreck, navigate a boat around the Solent, and send down divers, but developed decision making and problem solving skills. Ballooning simulated flight over various kinds of terrain with choices made in relation to height and wind strength and direction. However, children discovered that the questions were not random. The result was that they could learn the way through and then tell others in the class.

Simulations such as Granny's Garden were successful because they were exciting and stimulating for children. They gave opportunities for talk, decision making and predictive writing (Watson, 1986), and the depth of engagement through pleasurable involvement in the game overcame the issues of scarcity of machines, background noise, and poor preparation for the task. The activities were easier and familiar activities and thus more comfortable for teachers to handle at a time when they were so uncertain what they could or should do. The activities were flexible and could fit into the time constraints of a classroom day.

The attractiveness of simulation was often because teachers' notes accompanying the early simulation software set up the rest of the project. Children had to use the reference library, worked in groups on one aspect such as read and listened to a story about going on an expedition. Children drew and made models and devised plays – away from the computer. It was seen as a good thing that children were not at the computer all the time. Indeed there were not enough computers for children to use anyway.

Some simulations also had the benefits of simplicity not present in today's multimedia structures in the sense that they had only function keys to operate a limited range of options. The limits of the software and memory defined the way Granny's Garden and Mary Rose worked in contrast to the complex, time-consuming activities of CD-ROM projects such as MYST. It was only possible to create simple graphics on the screen, with few words. The result almost by default was a simple structure that children could easily follow. The possibilities of becoming lost or not understanding the cluttered screens did not often arise.

The BBC explored the growing potential for selling simulations. The researcher was personally involved in discussions as to ways of applying traditional high quality production values to the new media. Those values included activities which could be contained within the time scale and organisational limitations of a classroom timetable. These were the values underlying the Climbing Everest, Flight and BirdSpy created by the researcher for the BBC Micro. The subjects also had radio programmes that set the emotive and imaginative scene for the measured activities in the software. Attractive subjects that had general as well as educational sales potential were deliberately chosen.

According to (McFarlane et al., 2002) there is very little change in the specific educational approach to games and simulations.

> It seems that the final obstacle to games' use in schools is the mismatch between games and curriculum content and the lack of opportunity to gain recognition for skill development. This problem is present in primary school, but significantly more acute in secondary (p. 4).

Simulations invite learning but do not guarantee it and learning is not so easy to quantify. They are hard and therefore expensive to create and each child needs to spend a lot of time at a computer. Perhaps it is because multimedia simulations such as Sim City and MYST though beautifully created are extremely complex and require a powerful computer, skilled teachers and curriculum time that is not available. There are examples of their successful use in

Australia including Exploring the Nardoo but significant teacher input and commitment is required.

The Research Tool presented an opportunity to rekindle interest in simulations using BBC resources. The Research Tool, instead of considering simulations in terms of skill development and learning outcomes (McFarlane *et al.*, 2002, p. 11) explored the pleasure element of 'gaming' in the context of improving the quality of interaction through depth of engagement and is pursued in the second section of the literature review.

Carr and England (1995) considered simulation as the basis for developments in virtual environments. A natural successor of simulations in the adult environment was virtual reality and according to Carr and England it 'can provide high levels of engagement depth across a wide range of abstractions' (p. 211) in terms of knowledge gained, length of time used and user satisfaction. Virtual reality technology was outside the technical possibilities of the research at the time. The Research Tool explored on the simulated 3-D perspective which was achievable with the software available.

The discussion of different software types is used to provide a background to the increase in pace of developments (prior to the period of the Research Tool's development) that are the concern of the thesis and in particular the nature of technology research, which is the focus of the next section.

3.2.2 Information technology research (1980s-1990s)

What was the pace and extent of research into the use of computers in schools? Summarising the events of the 'watershed' of the National Curriculum – before the 1990s – can be best described as a fitful set of research initiatives. In the early 1980s computers were first introduced into primary schools. Financial incentives were used to encourage schools to do so. But there was no focus, no national curriculum. The computer was such a new tool that the context was to see what educational potential could be achieved by writing code. The official approach to the developmental process was entirely in keeping with current educational policy – the practice of funding specific developments with short-term strict deadlines and by a gradual permeation of ideas using the traditional cascade approach. There is little change today – a primary school in 2001 might have 39 such 'pots' of funding each with a report to be written and an inspection to confirm its accepted application.

The process in the new area of computers was achieved through the Microelectronics Education Programme (MEP), which begun work in 1981. There were primary focus groups operating as centres of excellence and good practice such as King Alfred's College in Winchester. Individuals, including teachers designed and created specifically classroom based educational software. In addition, the BBC took a leading role by marketing the BBC Micro as a nationally available educational computer. It was not until 1987 that the next Macintosh II and the Archimedes computers were introduced, shortly followed by the publication of the Microsoft Windows graphical user interface, which included software for word processing and database creation.

Did the speed and extent of the impact of research change from 1981 onwards? According to McFarlane (1997) the answer was a confident, yes. In 1989 the National Curriculum was introduced which established that information technology had to be taught. IT became an Attainment Target in the Technology Orders. However, by 1995, IT was not being taught in school to any extent. The reasons were considered to be lack of resources, cost and lack of staff training (p. 5). Various MEP pump-priming initiatives were introduced to ensure hardware and software including the new multimedia products got into schools. The extent of the impact was limited by the learning model which was still the 1980s 'cascade' approach, and ineffective, because it lacked a focus on training for teachers (INSET), (Cox, 1999). Table 3.1 is a brief chronology of government policies and significant events in IT showing the increase in pace of policy implementation during the period.

1981-1984	Microelectronics Education Programme (MEP) Micros in Schools Scheme with teacher training (cascade model) and subsidised computers
1985	MEP extended, free modems for schools 1986
1987-1990	Microelectronics education support unit (MESU) established National Curriculum begins
1992	CD-ROM in Schools Scheme. Interactive Video, edutainment and business software
1992	Grants for education support (GEST) from the DES
1993	NCET Looking at Laptops project
1994	CD-ROM in Primary School Initiative
1995	Superhighways Initiative Office for Standards in Education (OFSTED) inspections begin GEST, IT in subjects
1996	Initial teacher training in IT begins
1997-1998	NCET produce series of television programmes about using IT. Rapid growth of schools on-line Integrated Learning (ILS) in schools
1998-2000	Teacher Training in IT New Opportunities Fund and TTA initiatives

Table 3.1: Chronology of government educational Information Technology policies.

It can be argued that the really significant change in educational IT came about not by a planned development and the role of the MEP, but because of a group of factors surrounding popular demand, fashion and parental expectations in the early 1990s. A significant role for popular demand is a case put forward by Young (1988). Up to this time schools used software delivered on the BBC Micro and similar computers that children and teachers could not use at home as in the manner of the later PCs and the Windows environment. The new mass marketing of IBM and Mac II personal business computers were also advertised in the domestic market as having an edutainment value in the home. These computers used the new graphics-based user systems interface. They were fitted with CD-ROMs and were sold with 'bundled' edutainment CD-ROM software, often based on existing books and encyclopedias. What can be identified is at this same time there was a move to organise effective research in IT (Cox, 1999) for reasons described by Waxman and Walberg (1986) in more detail below.

The requirement for more organised research was part of a political movement for improvements in education and by 1995 IT in the National Curriculum was established as a subject in its own right and had to be taught (DfEE, 1995). Schools were now required to improve IT standards. Research in how IT should be introduced and what educational value could be achieved developed in parallel. The decision that IT should be taught through subjects in reality caused staffing and cost problems for schools. The result was that IT tended to be taught as a separate subject in dedicated computer suites for staffing and resource reasons. Schools that did teach IT as a separate subject emerged well from OFSTED because they met the key inspection targets.

Since 1998 there has been a further development – the extension of IT to include communication technology – and the acronym ICT is now in common usage. The initial teacher training curriculum for the use of information set new statutory standards for equipping new trainee teachers with the knowledge, skills and understanding to make sound decisions about when, when not, and how to use ICT effectively in teaching particular subjects. The result was that trainees were being taught to use ICT within the relevant subject and level in the National Curriculum, rather than teaching how to use ICT generically or as an end in itself. There has also been the establishment of examinations (GCSE) in ICT. The focus has moved on to the real world use of computers reflected in the similarity of academic (GCSE) and vocational (GNVQ) course content.

Having summarised the key features of the period 1980s and 1990s, the next stage of the argument was to consider the quality of developments in research before and after the watershed of the introduction of the National Curriculum in 1989 in more detail. Trends in IT teaching during the early period of this study were illustrated by comparing the keynote speeches at the computer-assisted learning (CAL) conferences in the UK in 1983 and 1989. The comparison provided an insight into the changes in approaches to IT. By 1995 the theme of the CAL conference (Kibby and Hartley, 1995) was 'Learning to Succeed, draws upon the experience of the widespread use of the microcomputer in education over the past decade in order to assess the use in the future millennium. It attempted to answer such questions as what will the future look like and what lessons could we draw upon from the past to guide us?' (p.1).Bork (1983) at the 1983 CAL conference saw the future of computers in education as depending on solving issues of the widespread future use of computers, confirmation that computers would lead to a better not worse education system, an effective production system for education programs and institutional change (p. 4). He suggested that much of the software material including commercially published materials were also of very poor quality (p. 1). Enough experience had been gained by 1989 relating to Bork's view to categorise the use of computers and express doubts about the rationale for introducing them in schools. For example at the 1989 CAL conference Hawkridge (1989) asked 'Who needs computers in schools and why?' Analysing four rationales for using IT in schools: increasing awareness, learning computer programming, learning word processing, spreadsheet and information retrieval, as well as learning selective topics, he suggested it was not teachers who wanted computers in schools but the policy makers and the multinational companies who wished to sell generic software and hardware (p. 2). In the context of the speed of the development of computers adapted to specific educational use, Russell (1996) argued that IT in Education in the 1980s might have evolved much more slowly were it not for the improvisation of primary school teachers.

> By the 1990s schools had gained enough experience to express doubts about the rationale for introducing computers in schools.

For example, Hawkridge referred to the awareness argument, 'let children use computers and they will learn about computers and any subject'. He considered it to be flawed as a waste of resources. Also that the 'preparation for the workplace' rationale he considered was not backed up by the resources to use computers to the best advantage. Most importantly, Hawkridge identified that there was a lack of good educational research carried out up to that time.

Hawkridge was echoing a long-held doubt concerning educational policy. Shaw (1982) has suggested that educational policy was usually an attempt by society to get the education system to solve problems that it cannot solve itself. Shaw noted that these objectives are not being achieved without in-service training, finance and enough staff and teachers whose dominant role was to create software.

The concern for good research in education was a relatively recent attitude. Evidence to support this argument was provided by the history of the main national body promoting the use of IT in Britain, the National Council for Educational Technology (NCET). NCET was established in 1988. It was an executive non-departmental public body with charitable status. The Secretary of State for Education and Employment in consultation with Secretaries of State for Wales, Scotland and Northern Ireland appointed the members of the Council. It replaced the SCAA, formerly the Schools Council. NCET, then became the British Educational Communications and Technology agency (BECTa) in April 1998. Only since that date was there a requirement to provide research references to support evidence for good IT practice in schools. In fact the first major publication providing research information of this kind was in 1994 (Brown and Howlett, 1994). This brief pamphlet contains references of 122 papers, of which only 38 date from 1990 or before.

One of the reasons why educational research was limited before the watershed of the National Curriculum was put forward by Bork (1983)who asserted that programming languages were useless in generating educationally useful computer-based learning materials (p. 1). The software for creating the learning materials had to be written by the designers first. Generic authoring programs such as Director (which once required the power of a mainframe computer) ran on a desktop PC and enabled an educational software company to avoid writing program code to create each new individual multimedia classroom resource didn't arrive until the 1990s. However, Hawkridge could not predict the speed of commercial authoring software development and the greater range of integrated interactive techniques incorporated in any one package. By 1994, the authoring programs speeded up the creation of new products, cut costs and allowed the developers to concentrate on designing educationally useful content. By then

British schools were even able to purchase software called HyperStudio to allow children to make interactive material themselves.

Young (1988) found it was not government schemes that had the greatest impact on the role of IT in Education. Schools became part of a trend. Young points out that change frequently occurs in education due to fashion rather than research, and that computers reached school as a result of trends in society. Prophetically anticipating the huge growth in PC computer ownership, reductions in price and availability of software were the dominating factors in the early 1990s. Just as significantly, Young also suggests technological innovation was different from other innovations because of the enormous range of tasks a computer can undertake. He considers that the study of a link between innovation and research will illustrate the reasons why IT was introduced in schools.

Sage and Smith (1983) offer a simple reason why there was a lack of research.

> The educational worth of computers was relatively unknown in primary schools by teachers, heads, advisory bodies and researchers. Such knowledge has developed after acquisition (p. 40).

Self (1985) also identifies the pervading priority that hardware should be introduced first, criticised the available software and called for more research:

> While the United Kingdom government can spend £30-£50 million on putting computer hardware into schools the Research Councils are struggling to raise £500,000 to support related research (p.168).

Waxman and Walberg (1986) suggested that education IT practices in the 1980s were based on unexamined assumptions, with little empirical data, referring to the work of Howey (1977), Tabachnick et al., (1980) and Waxman and Bright (1986).Waxman and Walburg also suggested one of the reasons for the slowness in growth of research was the poor research methodology of the period. Researchers tended to formulate problems that they have the skills in solving and studies used different methods and created contradictory conclusions. However, the political mood changed. By the end of the decade an increasing imposition of education policy from central government also included a general concern about IT in education and resulted in more research being carried out, methodology was also improved and there was an active argument about what constituted good research. Teachers and educators had become both producers and consumers of educational research (Doyle, 1990). The methodology of this thesis was informed by these developments and great attention has been paid to thoroughness of techniques employed.

During the period (1980-90) the long tradition of teacher involvement in 'grass roots' curriculum development changed generally with the imposition of the National Curriculum towards a more centralised 'top-down' model. Early in the period (1970-80) the views of Advise (1982) argued that development occurs within the existing curriculum. That teachers should be researchers, the teacher-centric model had been a central theme from the 1970s and the view of Stenhouse (1975). In the 1970s Bruner and Stenhouse were the source of inspiration. An example of their model was the researcher's anecdotal experience at the Regional Resource Centre at Exeter Institute of Education at that time. Teachers were encouraged to get together and analyse, discuss and develop curriculum materials to meet the learning objectives that they defined for themselves. The role of the Resource Centre staff was to create educational resources using the new miniature cameras and tape recorders and photocopiers that had just arrived on the market. However, this early form of pragmatic educational research using teachers to create learning resources required a high level of training and practice. It was also a decentralised model, out of favour as the centralised National Curriculum was introduced. It is arguable that even though the teacher-centric model is valuable, teacher-based IT research became swamped in problems of the technical knowledge and time-consuming programming. This was the experience of the MEP project (Noss, 1984d).

Watson (1989) found the debate about IT research had changed between the 1980s and 1990s. The focus had been the relative merits of different programming languages, and the structure of computer awareness courses. In the 1990s the discussion shifted to a consideration of the relationship between computers and the curriculum.

Concerning the quality of educational research in the latter period of the National Curriculum watershed, Maddux (1993) was still critical.

> ....nothing miraculous happens automatically as a result of putting a computer and a child in the same room and that research studying the technology and its infusion into the classroom is extremely limited (p. 14).

Maddux made a series of observations about general attitudes to the need for children to program computers to get good jobs and the need to boost the nation's faltering economic health, which illuminate the limitations of IT research in the latter period. They confirmed, in an American context, the argument expressed by Hawkridge (1989) in regard to the industrial interest in education in the UK.

Maddux (1993) also reported that more research was done in the 1990s, but it was simplistic i.e. the skills were not defined, with conclusions couched in terms such as:

> If learners are taught to use computers they will improve more in....(some skills) than an experimental group who are traditionally taught (p. 7).

Research shifted to teaching children to program using Logo rather than exposure to demonstrating its use. The major problem of this period, Maddux concluded, was that researchers ignored both teaching and learning variables. His observation was grounded in recognising the practical realities of a busy classroom and has special significance to this thesis. The Research Tool for this thesis was software especially designed to be effective within the operational limitations of a real classroom environment.

A third of Maddux's research stages was predicted from 1993 onwards, the stage which he described as concentrating on learner/teacher interactions. However, the only examples he used as a reference of the valuable type Stage Three research were; use of word processing, Logo meta research, and Special Educational Needs (SEN) (Guddemi and Mills, 1989), research undertaken before the introduction of interactive CD-ROM products, an important omission which this thesis attempts to rectify. Even so, most significantly, Maddux (1993) commented on the new graphical user interfaces being introduced:

> It seems incredible, but I have never seen any serious theoretical discussion of whether graphical interfaces are consistent with what we know about the way children think or

> learn, or whether clicking a mouse on icons has any concrete advantage over typed word commands (p.12).

As an example Maddux (1993) also reported that the Windows 3 with a graphical picture based interface being sold commercially as an educationally valuable product with no evidence that it had educational value. 'No one has studied it in an educational context.' (p. 13). Benzie (1988) a year after the introduction of the Windows environment reviewed the potential of Windows Window-Icon-Menu-Pointer (WIMP) environment and expressed concern about the cost, skills and time required for creating education specific software (p. 212). Similarly, the first Mac graphical user interface on the market in 1984 interface was tested extensively but not with children or in an educational context. These observations evidence the lack of classroom level testing of the new graphical user interface based software at the time. This was not to ignore considerable testing of the Windows environment in an adult context (Billingsley, 1988) concerning technical problems of computing power and with adult user issues such as helping people understand windowing operations (p. 433). Testing of children's reactions to multimedia graphical user interface software only happened later (Brown and Howlett, 1994).

What Maddux also describes in his paper are that the features of the successful international marketing operation by Apple completely bypassing educational considerations. Maddux considered that Apple took advantage of a western cultural consensus that typing was regarded as a low-level e.g. secretarial skill and that managers therefore refuse to use the computer as a demeaning activity. The Macintosh interface was sold to managers on the basis that there was no typing involved and that the mouse was used to make more and better decisions more quickly. There was no reference to education in the Macintosh human interface guidelines (Apple Computer Inc., 1992), which supports the view of Maddux that computers as an educational tool specifically for school use by children were an afterthought.

The evidence of the literature review at the time the Research Tool was designed revealed the lack of research into educational software and particularly the role of the graphical user interface in an educational context, which this thesis is intended to correct. The evidence for the hardware-based priorities of computer introduction into schools – informing the problems children experienced with managing a mouse, the CD-ROM caddy, viewing the adult-specific computer box and screen – also suggested the need to look further into the physical aspects of the child-computer relationship. Sage and Smith's earlier observations about the priority of policy to introduce hardware in the context of Maddux's references to lack of commercial marketing to the education section was to begin to build a pattern of government-industry 'hardware first' involvement; a pattern that has become increasingly transparent with the introduction of the Internet into schools.

3.2.3 Summary

The critical analysis of the introduction of information technology in British Schools has charted the significant historical events in IT and ICT development in the 1980s and 1990s. First, it has shown the influence of the National Curriculum in information technology in context of the shifting ground of what constituted IT learning in schools throughout the period. Second, the evidence suggested there were a range of factors including fashion and commercial that influenced the introduced hardware into schools prior to the creation of specifically designed educational multimedia software. Third, the inadequate staff development and little consideration of classroom practicalities have been revealed. Finally, the literature review of the significant historical events in the development of information technology highlights the poor quality research into IT particularly in the early part of the period studied. Overall, these factors illustrated the lack of attention to children's use of the computer in a classroom environment. In the next section a reminder of these contextual observations introduces each section of the detailed review of research papers in the related areas of study.

3.3 Interface design

3.3.1 Introduction

The second section of the chapter is a review of papers informing the study of the relationship between children and computers. The available research into computers in education in section 3.2, because of its quantity and quality was limited in providing answers to the contextual research. The research in this section also demonstrated that the scope of the range of subjects needed to be wider than conventionally accepted. The problem was that of the conventional educationalist's narrow view of users and the computer equipment they operated, specifically of the child-computer relationship in a classroom environment was not available to answer the questions posed by the contextual research. Therefore other relevant subjects informing the child-computer relationship were studied in depth. The question posed was 'What are the features that improve the quality of engagement between user and computer?' Emerging from the literature review was evidence of a wider set of relationships between user and computer. These relationships involved physiological and ergonomic aspects of human-computer interaction known in their specialised fields but not in an educational context, which might enhance the quality of engagement in educational computer interfaces. An argument was proposed a convergence of evidence for an alternative paradigm indicating ten features that may achieve greater depth of engagement between users and computers in an educational context.

However, the scope of the wider range of literature review required defined limits. The boundary was confined in the following respects:

- Researching the extensive field of visual search was limited to the foveal oval and visual field issues because of the contextual research problems of children performing educational tasks within complex screens.
- The study of ergonomics literature focused on the issues around definitions of the physical organisation of the user and the computer work station configurations, in so far as they have specific implications for the classroom environment and children using computers.

- The advantage of pleasure in learning was well-known in the education field, but did not form part of an academic framework. Initially promoted by the gaming potential of multimedia, the study was confined to simulation in an educational context and the components of deeper engagement through concentration during physical involvement called flow theory.
- Education theory was limited to investigating manipulation of objects and child development in a conventional context. The reason was to inform the significance of manipulation of objects on the computer.
- The subject of interface metaphor has been widely covered in human-computer interface literature. The thesis review confined the study to issues arising from the linguistic interpretation of metaphor in the human-computer interface literature. The reason for focussing attention on this aspect was because the literature research indicated metaphor had a physical component. Metaphor has significant potential for effective human-computer interaction in the learning process, as this thesis concerned a study of a holistic, whole body experience, specifically a child using manipulation with the mouse.
- The investigation of 3-D interface literature was confined to aspects that might inform the value of pseudo 3-D perspectives interfaces in the Research Tool. The review was not intended to be a comprehensive study of 3-D immersive environments literature because at the time education interface designs were generally limited in their full 3-D capability – for reason of cost.

Within the limits of the study, research into all these elements showed the integrated nature between brain-body relationships and together a coherence emerged that can inform methods of giving children a greater sense of engagement. The convergence was formulated as a set of criteria used to inform the research question and for the main study. Each aspect of the literature review begins with a reminder of contextual research and concerns of the Research Tool design during its development and ends with a short summation relating findings that clarify issues which are listed in the final summary.

3.3.2 Children's eye function, field of view and vision issues

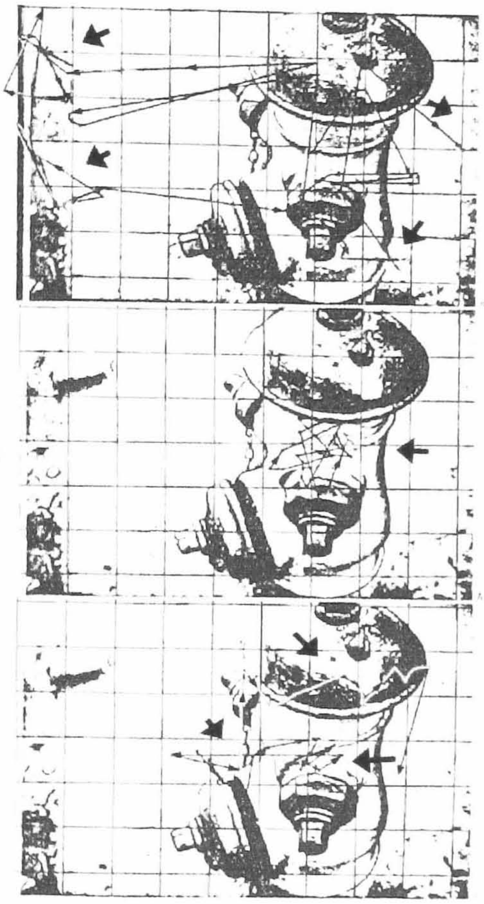
This section begins with a reminder of the prior observations that began the research of the relevant literature.

1. During the period of contextual research children appeared to ignore icons in the corners of the screen. There appeared to be a preference for the middle-left and middle-right of the screen. They also appeared to press some buttons repeatedly, and ignore others completely. They clicked anywhere quickly and at random and frequently moved to the next screen using the hotspots without attempting to read the contents of the screen.
2. The interactive products in the contextual research had a cluttered interface. What was the significance of busy screens – a lot to look at, small pictures, and navigation buttons of all shapes and sizes?
3. In early drafts of the Research Tool children could not identify movement in areas far from the focus of activity on the screen.
4. The contextual research raised the concern that the computer was an adult product. The CD-ROM disc case, keyboard and the mouse were not designed for little hands. Even the best-designed trolleys were too small for the computer, keyboard and monitor. From these practical issues came serious concern that in the process of learning children had great difficulty holding the mouse, manipulating the cursor over hotspots, holding the mouse still whilst clicking on hotspots and carrying out click and drag movements.

The relevance of eye function in the literature review was central. First, the contextual research observations proposed a closer investigation into the factors influencing the way humans study visual material; second, the physiological aspects of eye search had not featured in educational research due to the experimental approach to IT and other limitations as indicated in the previous section of the literature review.

The section continues with a survey of writings on eye physiology, primarily the work of Bruner and Mackworth (1970) who used an eye-tracking camera. Later, Bruner and Mackworth's findings are considered in the context of education by referring to the work of Piaget and Vygotsky.

In an educational context it was not common current practice to make connections between interactive design and children's visual search abilities. In relation to still images only, not interactive images, Hubel (1988) offered a standard description of eyes fixation and saccades or short movements to a new position. The eye was also alert to any object that asserts itself by moving slightly contrasting with a background, or presenting an interesting shape, either singularly or in combination. Bruner and Mackworth used an eye camera to record how the eye tends to oscillate around areas of visual interest of a photographic picture. However, they observed a difference in the eye movement between adults and children in the process of viewing still pictures. Pictures of a water hydrant *(Figure 3.1)* demonstrated the difference in terms of search patterns between children and adults.



Adult

6-year-old

5 to 6-year-old

Figure 3.1: Three individual eye-track records. Top: long eye track (66 inches from adult); Middle: extremely short eye-track (14 inches from a 6-year-old; Bottom: 5 to 6-year-old's preoccupation with detail (27 inches). Large arrows added to illustrate the extent of eye-tracks for each age group. (Bruner and Mackworth, 1970, p.157)

The image shows how 6-year-old children's eye movements oscillated around a small area of a picture. An adult tended to explore pictures systematically. The test was carried out using three levels of image sharpness. All results confirmed the same relationships. Yarbus (1967) attributed the differences to the apparent reluctance of children to make use of peripheral vision (p. 157) and lack of precision in the oculomotor system (p. 158). Mackworth (1965) also inferred that children fixated around a point when comprehending a difficult word and that the field of view was also reduced. He also reported (1970) that children make much larger leaps of eye tracking than adults do when the image was against a difficult background. The tendency to leap about extended to three inches or more as against one inch in favourable conditions. Other results of his research showed there was little consensus as to what was the agreed important feature of a scene. Also in terms of the direction of leaps of gaze, children failed to make vertical leaps, preferring horizontal search tendencies. Children also ended their gaze by making long leaps to large patches of colour, especially where these had a high brightness contrast with the background (p. 163).

Bruner and Mackworth showed eye search tracks in Figure 3.1 looking for edges. Hall (1969, p. 82) considered the brain in natural conditions automatically precues i.e. sees more clearly in terms of edges 'Edges create a cortical jolt and straight lines as edges are beyond those experienced in nature.' Gregory (1974) reported experiments in which individuals express a preference for images that use straight lines. A recognition of cultural factors where 'carpentered' features are rare was given by Deregowski (1980). A solution to the confusion of straight or curved line preferences for visual search stimulus appeared to be resolved by Hubel (1988) who described how the orientation of the end stopper cells in the eye are sensitive to both corner curvatures and to breaks in lines *(Figure 3.2)*. They were excited by borders 'We can thus view end-stopper cells that were as sensitive to corners, to curvature, or to sudden breaks in lines' (p. 85).

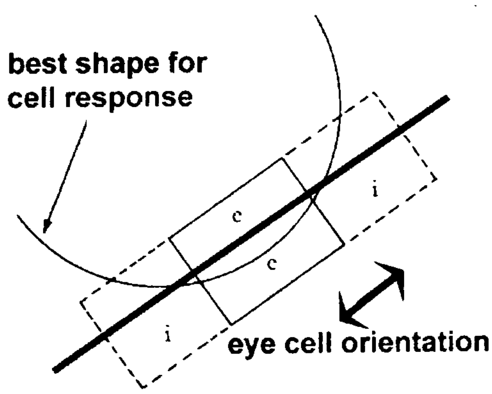


Figure 3.2: The best shape for stimulating activity in rods and cones. (Hubel, 1988, p.85)

An alternative reason for selection of areas of focussed attention was the spotlight model of visual attention, Eriksen (1988, p. 10), and since confirmed by others, which demonstrated that pre-cueing by 100-200m the location in a visual field, where a target subsequently appeared facilitated target identification.

In estimating the value of vision literature to the argument, Bruner and Mackworth's observations were only made with still images and before computers with graphical user interfaces. Whether modern complex interactive screens reveal similar patterns was speculative. The contextual research observations of extended leaps in unfavourable conditions, the tendency to horizontal search, the focussing around small areas of interest appeared to be informed by these studies. There were no references to Bruner and Mackworth's physiological approach to the complexity of screen design issues in guidelines or current writings. It is conceivable that multimedia screen 'pages' may be much more difficult for children to search for these physiological reasons. Further research will be required to clarify the supposition. Unfortunately it was beyond the scope of this study to employ the use of an eye camera to demonstrate Bruner and Mackworth's findings on current multimedia display conclusively. This was because of the time, cost of using an eye camera and the technical problems associated with the equipment.

Next, the role of the foveal oval was researched. The reason for the investigation was that the operation of the foveal oval may inform interface design because of the fovea's role in directing user's gaze at elements on a complex images on computer screens. Of particular interest was the narrow area of clear focus and further subconscious narrowing of vision as a reaction to movement of the mouse pointer arrow or moving events on an interactive screen.

The fovea is a small depression in the central region of the retina containing only cones, which are colour sensitive and capable of finer resolution of images. Gregory (1974) described the foveal area as 1 degree of visual field and being of greater acuity consisting of 2,000 cones, with the edge of the retina sensitive to movement, noting that when movement stops the object becomes invisible. The foveal oval was also termed the foveal lobe. Hall (1969) described the two fields of view – the foveal oval and the wide-angle view – as 'together creating an illusion of broad band clear vision.' The foveal oval represented an area in the scene which was: 'quarter of an inch wide at a distance of 12 inches from the eye. It extends 12°-15° in the horizontal and 3° in the vertical within the larger area of the ocular field of vision covering 90°.' Figure 3.3 simulates the area of sharp focus indicated by the centre circle and unconscious effect to the blurring of the edges. The average person, and especially a child is unaware of the phenomenon. The illustration does not fully accurately visualise the true oval shape of the fovea's area of acute vision as described by Hall or the extent of the field of view.

Figure 3.3: Double Portrait Tate Exhibition Wellcome Trust Sci-Art Project: The Painter's Eye Movements, 1991. (Ocean and Tchalenko, 1998)

The effect of a concentrated field of clarity that the foveal oval provides was further enhanced by the shape of the eyeball and a vertical plane such as a computer screen. First, the spherical plane of field of view in focus created by the shape of the eyeball, ensures that, as demonstrated in Figure 3.4, the edge of computer screen surface was naturally out of focus when a user was focussing on a narrow central area of the screen owing to the curvature of the eye lens. (*See also Figure 3.7*)

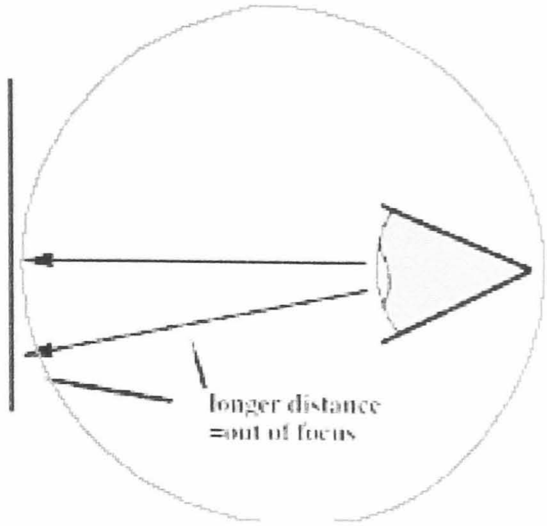


Figure 3.4: Diagram showing the limit of the area of focus at the computer screen.
(Adler, 1997)

Another aspect – the 'outer' limitation of visual field – may account for children tending to ignore corners of the computer screen; the human field of view was not rectangular. As shown in Figure 3.5, the top left and right of the stereoscopic wide-angle view of the visual field were not scanned in single fixed gaze.

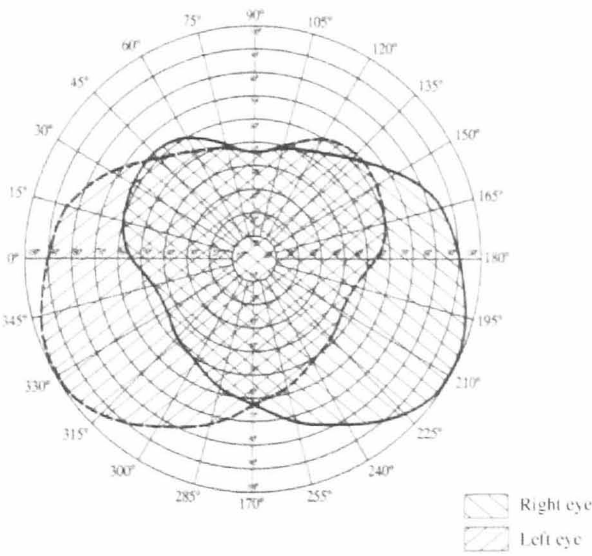


Figure 3.5: The ocular field of view as defined in standard eye physiology references.
(Kalawsky, 1993, p. 50)

Children staring at the screen may have 'blind' spots in these areas. Interface designers appeared to assume that the whole screen fills the field of view.

The argument in the context of this research was confined only to drawing attention to an effect on visual focus caused by movement of the mouse or movement of objects on a busy computer screen. The process of a logical visual scanning process of a visual field in a natural or print environment has been the subject of many studies summarised by Rayner (1998) and there was still no consensus of how the human scanning process of static visual content works, due to the complexity of factors involved. Noton and Stark (1974) suggested a sequence of eye search in adults with a broad A-shaped sequence as shown in Figure 3.6. But Noton and Stark had no reference to children's patterns of search.

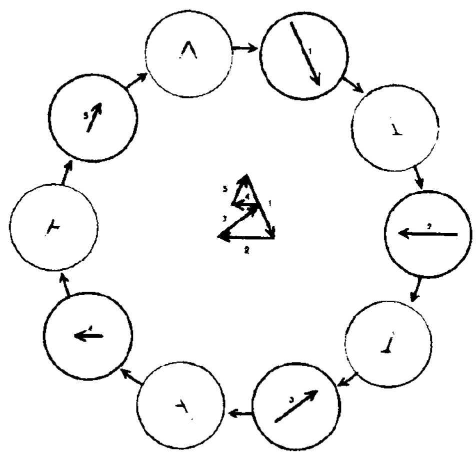


Figure 3.6: Modified Feature Ring takes into account less regular eye movements that do not conform to a scan path. Several movements which appear in 35% of recognition viewings, are in the centre of this ring. Outside ring, consisting of sensory (colour) and motor memory traces (black), represent scan paths and remains the preferred order of processing. (Noton and Stark, 1974, p. 122)

However, in a paper soon to be published Reichle et al., (2002) attempt to draw together the complex information processes involved in reading text, including the recent advances in cognitive neuroscience to propose a time sequence for eye movements, cognitive processes, and brain areas involved during reading a word.

In this section, research into vision; visual search patterns, how the eye tends to focus on small areas due to the physical structure of the eye, preference for edges and response to objects that move informed the design of the Research Tool by indicating ways to improve the quality of interaction. These discoveries suggested a simple interface centred in the screen with few features was an advantage. Awareness of these physiological factors could be of use to graphical user interface designers of educational products.

The next section of the literature review investigated another conventional assumption of educationalists, that a book – as an object – could be easily transferred to a computer. The need to analyse this assumption was that many early educational CD-ROMs became multimedia because the original resources were books and were developed by book publishers and their designers. The challenge to this assumption in this review was not on academic or literary principles, but the visual relationship of the reader to the book in a physiological context. The origin of the enquiry was the researcher's observations of children not reading the actual words on the screen when the book assets had been transferred to the computer screen, but to click on hotspots or buttons that had been added to the text by designers. The superficial cause was the propensity for children to click on highlighted, animated buttons. A deeper significance was proposed. The proposal was that a book held in the hand should be recognised as a three-dimensional object; the 'on screen' version was two-dimensional. The hypothesis was that a three-dimensional object transferred to a two-dimensional medium incurs physiological 'penalties'. The penalties might be the cause of children's observed problems. The purpose of this section was to illuminate the problem of the processes involved in loss of information between 3-D and 2-D elements on a computer screen.

Beck (1992, p. 4) in a study of visual processing in textural segregation demonstrated how diagonal slanting lines 18 degrees from the vertical embedded in a sequence of vertical lines were immediately easier to identify when the whole design was rotated 75 degrees backwards to the reader (to a perspective view). The easier recognition of diagonals suggested that textual images (letters) in a multimedia screen 'book page' display in a vertical screen may be easier to recognise on a screen sloping away from the reader with or without 3-D perspective visual clues. Enns and Rensink (1992) showed how improvement in visual search was also possible when shading was added to images. Enns (1988, p. 721) listed further advantages of a pseudo 3-D perspective field of view. The features that aid 'pop-up' resulting in faster identification times were not just line orientation, but also length, width, curvature, number, terminators, intersection, closure, colour (hue), brightness (greyness), flicker, direction of motion, binocular lustre and stereoscopic depth.

Two features aiding perception: orientation of the object – looking down, and light shading besides colour and motion stimulate pre-attentive vision or pre-cueing as identified by Gregory (1974). Smets et al., (1994) have recorded that to really have effect, shape and depth perception in 3-D displays should also have movement 'The movement of the observer has to be linked to motion at the workstation.' These features aiding perception, of looking down and pre-cueing were present when reading a real book but absent from the on-screen version; a real book held in the hand has print viewed at an angle, not at the vertical as on a computer screen. The current on-screen 'book' has none of these features of optimum viewing.

The potential significance of the child in relation to the computer and the orientation of the computer screen itself was considered next. At this stage in the argument, in an educational context, the concept of an optimum viewpoint was tentative.

Children reading text on a CD-ROM 'book' were in a quite different configuration to a normal book reading position as illustrated in Figure 3.7 by Mach .

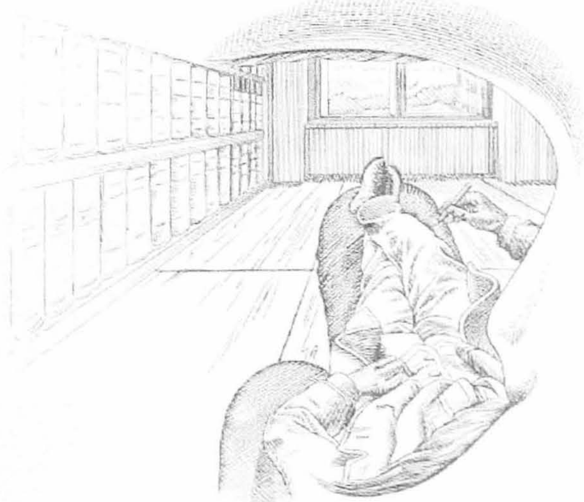


Figure 3.7: Mach observing visible parts of his own body and the surroundings (Held and Durlach, 1991, p. 238)

The artist illustrated one of the natural positions for reading; looking down, comfortable. secure and with a field of view with indistinct periphery images. Mach illustrated a natural reading position which was similarly a desirable position of a computer user reading in a natural posture for reflective, engaged activity. The ergonomic aspects of the reclining figure in contrast to the British Standards regulations was considered further in the ergonomics section of this chapter. At this stage of the argument for a revision of the way children used computers in an education context, the scene had three vision issue elements of significance. First, the centre of the field of view was in greater acuity for the reasons already accounted for in Figure 3.4. Second, the natural field of view also takes in an awareness of one's own body as part of the picture. Kalawsky (1993) considered the definition of virtual presence to be greatly enhanced by seeing parts of one's own body:

> A very strong feeling of presence can be achieved if the visual system allows the actual lower part of the operator to come (sic) into the field of view at the appropriate time.
> (p. 81)

Third, not clearly visualised in the drawing was that according to recent research by Intriligator and Cavanagh (2001) the lower visual field was physiologically more effective in terms of greater acuity and faster response times than the upper visual field. Therefore greater acuity in the lower visual field was reviewed for implications to this research.

In commercial marketing studies of supermarket purchases, it was reported that shoppers show a preference for items that were below the horizontal eye-level position indicate in the visible surface area in Figure 3.8. Stoper and Cohen described that in the normal terrestrial environment humans required three types of viewpoint: surface relative, gravitationally relative and head relative eye levels, corresponding to the angle at which the head was held.

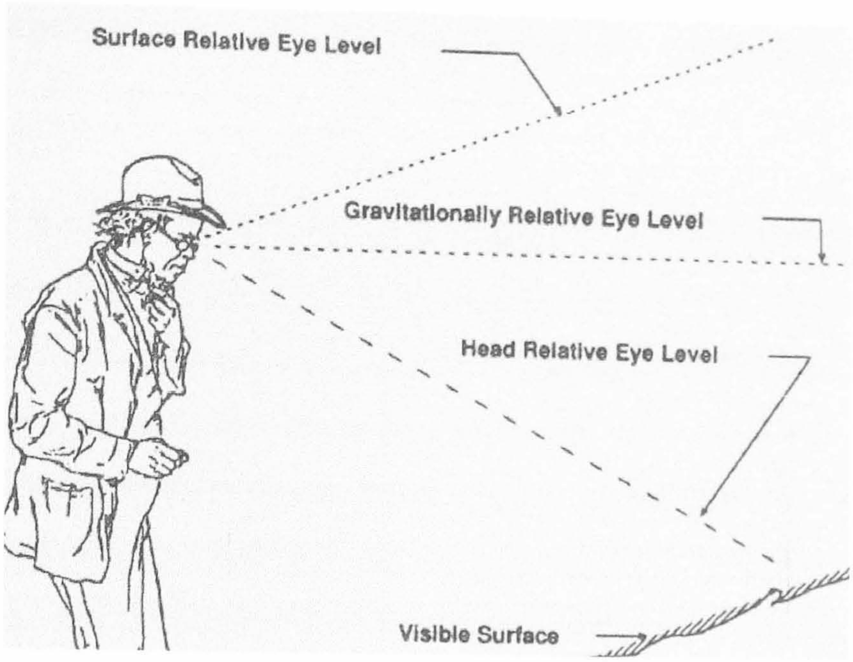


Figure 3.8: Diagram: Three types of eye-level viewpoints in the normal terrestrial environment. (Stoper and Cohen, 1991, p. 391)

This phenomenon has been known for some time (Enns and Rensink, 1992) where 'objects are more easily apprehended when they are below the line of sight and also when they are lit from the same direction.' (p. 722). Maddess et al., (2000) also found, in a study of diagnosis of glaucoma, that there were finer responses to stimuli in the lower visual field.

In a computer user context, Cochrane (1996) proposed a general preference for head-down operations at the computer as being more efficient:

> If I gave you a sheet of paper and a pen and asked you to write a note, I would be amazed if you held it at head 'home page' height and proceeded to write. I would expect you to sit down and crouch and write looking down. For various reasons locked into our distant past, we happen to be about 20 per cent more efficient when we read and write looking down on a sheet of paper than when we look straight ahead. (p. 10)

Intriligator and Cavanagh (2001) identified specific advantages of downward gaze in terms of finer resolution in the lower field of the visual field – by 50% in a radial dimension and by 17% in a tangential dimension (p. 200). They proposed their observations challenge the spotlight theory of attention by Eriksen and St James (1986) and others. Intriligator and Cavanagh drew attention to the over presentation of the lower visual field in the occipital-parietal region of the brain which Van Essen et al., (1984) argued 'is required for the control of hand and arm movements'. The same part of the brain was the likely site for control and selection of visual attention.

In terms of not only visual acuity, but also speed of accessing information, the lower visual field has advantage. Sheedy (1990) showed an optimum response time (4% improvement) to photographs from a computer screen at 50 cm for 10 degrees of depression when a head-and-chin-rest fixed the head location with the frontal protrusion of the chin and a point just above the brow line aligned in the vertical plane. Mamassian and Landy (1998) reported humans preferred to interpret ambiguous line drawings as representing objects seen from above rather than seen from below; and Rubin et al., (1996) indicated the task of identifying the segmentation of an image into figures and background was shown to be performed much better in the lower visual field.

Another, additional factor that influenced the preference for viewing objects in a downward gaze – the vertical horopter – was proposed by Ankrum et al., (1995). The horopter is a vertical line starting from between the viewer's waist and feet and projecting outwards. The stereoscopic mechanism operated in conjunction with eye cell sensitivity to colour in the red and green spectrum, consistently placed elements in a vertical plane below the line of gaze in front of the vertical plane, and above the line beyond the vertical plane as shown in experiments by Cogan (1979). A viewer identified the most efficient angle of downward gaze by fixating on the centre of a vertical wire. The vertical wire was seen as double until the wire was tilted backwards to a point where it appeared as a single line. At this point the optimum angle of view was defined for that user. A user may vary in their preferred angle of tilt. Researchers collated data from verbal responses to three screen angles – tilted towards the user (negative) 40°, 15° away and 40° from the user (positive). A user was placed in high screen position – eye level horizontal to the top of the screen and low screen position – eye level 20° above the top of the screen. Users reported significant preferences for the positive 40° angle at both high and low position (p. 134). The authors considered a vertical screen orientation to be inconsistent with the human visual system and proposed 'the vertical horopter may play a role in visual and postural discomfort at computer workstations' (p. 135).

In contrast to the evidence in this section for information to be presented in the lower visual field was the actual viewing position of children looking at a CD-ROM 'book' in an educational environment. The contrast was illustrated in Figure 3.9, photographed by the researcher at a school during the main study. Children were looking at the screen at varying vertical and horizontal angles. The classroom conditions illustrated in Figure 3.9 are still by no means uncommon in schools.

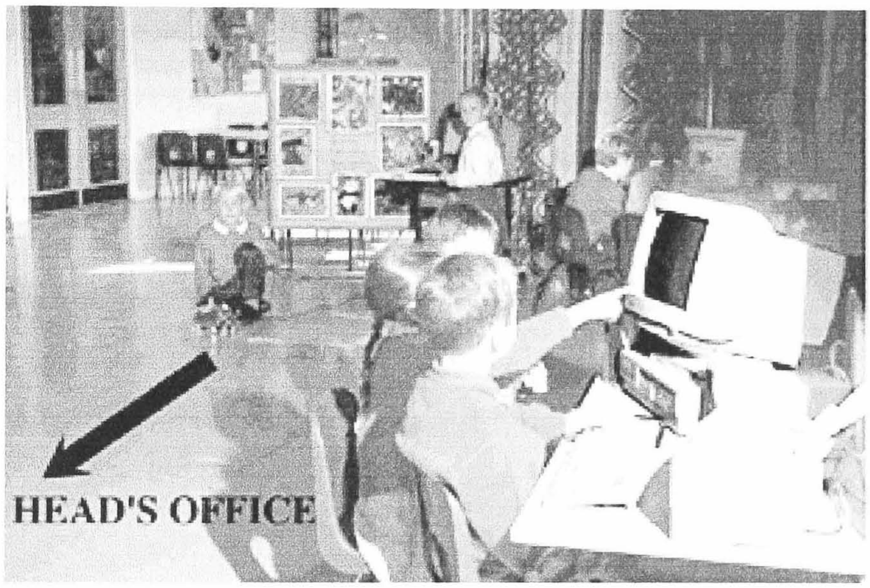


Figure 3.9: Children viewing the computer screen on a special commercial computer trolley (Howarth, 1995a, p.1).

The viewing configuration was less than visually efficient for the three reasons made in reference to Mach's image illustrated in Figure 3.7 above. The cause was often due to the limited space on a computer trolley. A further visual problem was added by the common practice of more than one child looking at the screen at once. Sedgwick (1992) reported close viewing distorts geometrically specified virtual space. For example, a square grid was distorted into a diamond. A side viewpoint created a shearing of virtual space, so a square grid had its upper side shifted laterally to form a parallelogram. A similar effect occurred when the viewpoint was too high or too low.

The literature review in this section informed the Research Tool to the extent that eye search in children suggested simple, central screen images were preferable. Evidence about the preferences of downward gaze and sloping visual field suggested changes to existing height and orientation of computer screens in the classroom could also lead to greater efficiency in vision. However, the findings were not incorporated in the Research Tool because of limitations in computer screen configuration. Finally, the pattern of sharing three children to a computer was likely to remain in schools. In 1998 there were twelve computers per primary school (DfEE, 1998) and in 2000 seventeen computers per primary school (DfEE, 2000).

In the next section, the issues surrounding existing height and orientation of computer screens in the classroom – the field of ergonomics and the origin of the official standards for optimum computer viewing conditions – were studied in greater detail.

3.3.3 The role of ergonomic and human factors

In the contextual research the following aspects were observed:

1. Children appeared to have had a series of physical problems associated with managing the computer, the keyboard and the computer desk itself.
2. The classroom was a crowded place. The computer and keyboard were usually put on a narrow school desk, with the monitor on top of the box leaving just enough room to fit a keyboard on the space in front and no room to use the mouse.
3. The computer may be put in full sunlight, in a corridor, anywhere there was room. What was the significance of the poor ergonomic conditions of screen, desk, mouse design and general usability in a busy, crowded environment?

During the huge growth and interest in ergonomics over thirty years there appeared to be, as far as the research reveals, no specific references to computers in education of children or education generally, except by Pheasant (1986) who observed:

> Once common, sloping desks have all but vanished from our schools and offices. Should the ergonomist mount a campaign for their re-introduction? (p. 194)

He reported Bendix and Hagburg (1984) who, in an adult context, evaluated horizontal desks with slopes of both 20° and 45°. They found that trunk posture improved with desk slope during a reading task. However, whilst subjects clearly preferred the *steep slope* for *reading* they preferred a *horizontal plane* for *writing*. Pheasant suggests the best solution was to allow for the option. He concludes:

> Despite the extensive research a surprising number of controversies remain unresolved. Should the seat slope forward, should the writing surface slope, should the operator sit upright or recline? (p. 196)

These very early, unresolved controversies were not referred to in the set of guidelines for computer users, an example of official guidelines for one person and one computer by organisations such as the British Standards Institute (BSI) illustrated in Figure 3.10.

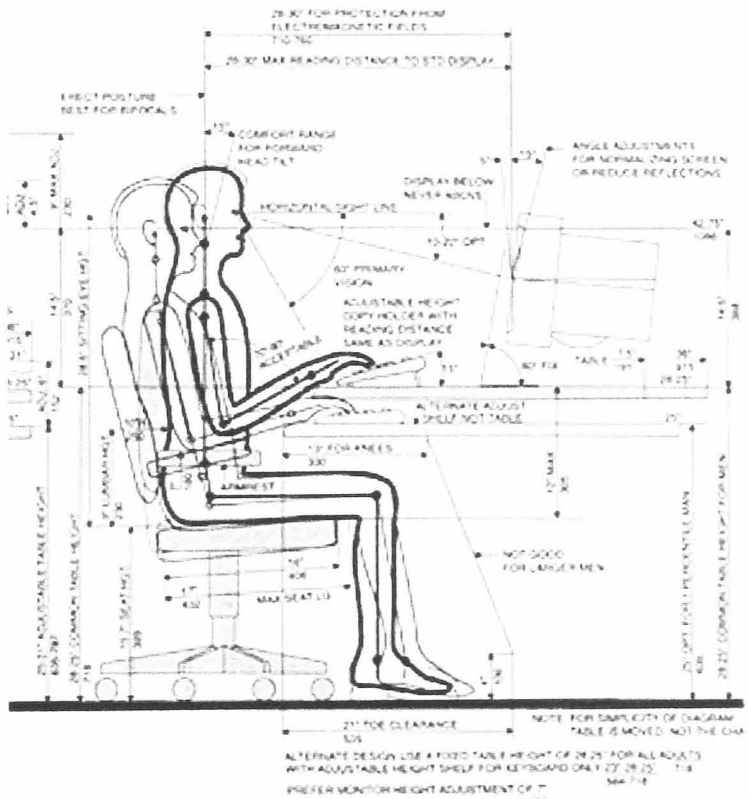


Figure 3.10: British Standards Institute average man computer station measurements. Shown for general orientation only. (Karwowski and Marras, 1999, p. 25)

The BSI standards in Figure 3.10 indicated users should have a near straight back position in contrast to a natural reclining reading position of the back, and to be looking downwards at 20°.

The regulations are based on ergonomic considerations, which are related to back posture. The school IT bench design are also defined by: standard school door width, and traditional (woodworking) workbench dimensions. In practice, general rules are plainly ignored as in Figure 3.8 and in general by the variable situations of room and lighting availability in schools. Figure 3.8 is a current dedicated school computer trolley design, yet it only allows the monitor to be placed on top of the PC, forcing the child to look upwards.

Hill and Kroemer (1986) questioned early ergonomists' suggestions for an optimum viewing angle and suggesting a variety of viewing angles from 10 to 38 degrees below the horizon, indicating the possible cause as problems associated with defining what was horizontal. They confirmed 'a basic preferred declination of the line of sight' (p. 129), the cause being the six muscles that hold the eyeball in tension and which are in minimum contraction when the eye was in a slight downward direction. They indicated that there was a range of angles preferred by subjects, especially as they lean forward when a steeper angle of view has been observed. They proposed 'one should place the monitor closely behind the keyboard, not on top of the disk drives (CPU)' (p. 134). Kroemer et al., (1994) reported not one but several optimum visual positions when operating different kinds of computer equipment. They again referred to 'putting the monitor on a CPU box is rather uncomfortable for the viewer' (p. 444).

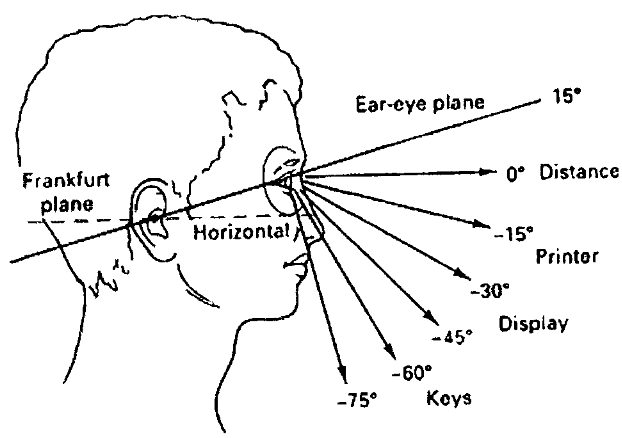


Figure 3.11: Suggested angles of line of sight with current computer workplace technology. (Kroemer *et al.*, 1994, p. 144)

The variation of backrest position was rigorously investigated (Burgess-Limerick et al., 2000) the results indicating that a computer workstation should be 15 degrees below horizontal eye level. They confirmed the findings of Bergqvist et al., (1995) that there was an association between eye-level computer monitor heights and neck discomfort.

Two studies showed a different research approach into identifying the preferred angle for screen orientation. Instead of controlling the head position with rests and restraints and being concerned with the quantitative data of the body orientation, these reports focus on subjective responses to comfort and viewing angle preferences. Highest scores were achieved at a monitor angle of 35% with a research rig placing the TV style monitor next to the keyboard (in the similar position to the current laptop) (Quaranta Leoni et al., 1994). A reduction in fatigue was attributed to the fewer vertical saccades required between keyboard and screen and they suggest a 'lowering of the VDU actually results in less visual fatigue' (p. 196).

The exploration of the role of ergonomics in this section identified unresolved controversies about an agreed standard for writing and reading positions at the computer. The evidence was still not conclusive as to the preferred angle of downward gaze or for the slope of the screen in relation to the viewer. The research indicated that individuals vary. In this section of the literature review the research found no studies of visual or ergonomic efficiency of the same tasks on a head-down laptop and a head-up screen on CPU box in a real world environment – the conditions in many UK schools and colleges.

In addition, there appears to be no evidence discovered in the literature review that educationalists recognised the possible educational implication of: user's head position in relation to the computer, the orientation of the screen, the distortion of images or less than optimum viewing positions of children. The current review of ergonomics descriptions of the relationships between a child and a computer appeared limited in scope. Changing computer screen orientations and ergonomic factors to achieve optimum viewing conditions in the main study for the Research Tool were outside the scope of the study. The next section examined other methods available of improving optimum conditions for computer interaction in the classroom.

3.3.4 Pleasure in learning

The potential for learning and pleasure at the computer was studied in this section. If the optimum position of a user and computer were difficult to obtain in terms of viewing angle of screen and its relationship to the keyboard and mouse and the images on the screen in the Research Tool what other features of interface design might provide optimum conditions in terms of a deeper sense of engagement? The emotional content of interaction was considered. The relationship to the previous section's literature review research arose from the educationalists' recognition of the pleasure children had when using computer games at home and in the classroom and from the contextual research.

In the contextual research children were observed:
1. Working away without any sense of time.
2. They chatted, concentrating intently.
3. They expressed their pleasure in the CD-ROM educational materials in relation to their quality of experience with computer game playing.

The role of pleasure and fun in learning focuses on the physical activity, the relationship of the mind to body and the sense of well-being that results from the whole body (holistic) involvement.

Vygotsky (1962) stated 'In play a child is always above his average age, above his daily behaviour, in play it is as though he were a head taller than himself' in considering that conceptual abilities of children were enhanced through play. There were respectable educational precedents in the use of simulation in a historical IT context (*see 3.2.1*). The value of the emotional learning content of the Turtle in Logo was also described by Taylor (1980). Malone (1981) explored the reasons for the attraction of games and how features could be transferred to computer-aided learning. He defined three elements: challenge (goals and scoring), fantasy (features such as 'explore within' arrows and drama) and curiosity (music and forms of feedback) (p. 81). Malone referred to the physical and emotional processes involved in traditional learning by doing evidenced in pertinent titles such as *Learning Through Activity*, (Anzai and Simon, 1979), and *The Use of Gaming for Motivation*, (Atkinson and Birch, 1978). The roles of mental imagery and associative learning have been established from the psychologist's perspective in the work of Bower (1972) and Buzan (1989). However, Malone considered that visual effects alone may entertain but be less educational but that environments varying in difficulty level 'increase both challenge and potential for learning' (p. 82). He also posited, that the real potential for computer learning was in games he calls isomorphic, where cognitive curiosity was fully engaged.

Malone's observations have informed the Research Tool. The educational potential of gaming and particularly the 'varying levels of difficulty' concept were employed in the designing of a variety of tasks and the order of the activity pages. However, he was only able to predict the potential value for captivating sensory effects using computers because the level of interactivity at the time he was writing was so limited. The special value attached to isomorphism in the Research Tool was the connections made between the physical manipulation of the mouse as beater and the percussion instruments.

Csikszentmihalyi (1992) took a more comprehensive view than Malone and summarised, in his flow theory, as a result of a prolonged study of enjoyment and quality of life, eight components that provided the necessary phenomenology of enjoyment in the following list:

> 1. The experience usually occurs when we confront tasks we have a chance of completing.
> 2. We must be able to concentrate on what they are doing.
> 3. Concentration is possible because the task has clear goals.
> 4. Concentration is possible because the task has feedback.
> 5. One acts with a deep but effortless involvement that removes from awareness the worries and frustrations of everyday life.
> 6. Enjoyable experiences allow people to exercise a sense of control over their actions.
> 7. Children lose concern for the self disappears yet paradoxically the sense of self emerges stronger after the flow experience is over.
> 8. The sense of duration of time is altered; hours pass by in minutes.
>
> The combination of all these factors caused a deep sense of engagement through enjoyment that is so rewarding that people feel that expending a great deal of energy is worthwhile just to be able to feel it. (p. 49)

Csikszentmihalyi identified these features of depth of engagement to be experienced by children and adults alike in any activity and walk of life. He drew on evidence for children's pleasure in activity (p. 47) from Buhler (1982) using one's body in such activities as running and swinging. Also from Piaget (1952), who viewed that one of the sensory motor stages of an infant's development was characterised by the 'pleasure of being the cause'. Berlyne (1960) sought neurological explanations in terms of balance between incoming stimulation and the nervous system's ability to assimilate it. The approach of Deci and Ryan (1985) was to look at the pleasure aspect because it gave a person a feeling of competence, efficacy, or autonomy. In a description of enjoyment that suggests a resonance with Tuan (1977) about the loss of front/back body orientation being described as 'lost in the forest', Deci and Ryan described how a forward movement, when a person has achieved something but gone beyond what was expected, may not have been enjoyable at the time. But the novelty and the accomplishment override the moment and on reflection, become a memory of fun. Pleasure in itself is different to enjoyment through activity in that it requires no effort and concentration.

To summarise the relevance of this section to the thesis; the universal human qualities of Csikszentmihalyi's phenomenology of enjoyment suggested no conflict in relating elements of concentration and pleasure to deeper engagement through physical activity at the computer using the mouse as a manipulation tool or in varying the level of challenges in the computer activities. Csikszentmihalyi's work contributed by informing how the coherence of these elements improved the quality of interaction and created activities which can be replicated using the interactive technology of the Research Tool. In the next section education theory concerning the physical activity during learning was studied in more detail to inform the advantages or otherwise of the replication of physical manipulation on the computer.

3.3.5 Manipulation of objects and conventional education theory

The aim in this section was to explore in some detail elements in the wider readings of the literature review related to the quality of computer interface engagement that may have resonance in the conventional education theory of writers such as Piaget and Vygotsky. Specifically, relationships were inferred between the value of children's manipulation of objects in a natural environment as part of the learning process and manipulation on the computer, which may inform the significance of the physical child-relationship for a child involved in activity at a computer.

There was evidence for children having a close emotional relationship – attributing qualities of 'life' to objects they interact with or manipulate – as explored by Piaget and Vygotsky. Manipulation was seen by Piaget in the context of 'building block' theory, a process by which the concept of causation was learnt by children manipulating objects. Lakoff and Johnson (1980) considered manipulation as a 'gestalt consisting of properties that naturally occur together in our daily experience of performing direct manipulations' (p. 75). The significance of the role of manipulation was explored in more detail.

Piaget and Vygotsky were writing at a time when computers were in their infancy and graphical user interface had not been invented. Their findings were compared with Turkle (1984) who was writing about the time when children were primarily writing code on computers. 'Killing' was the term used by children to express what happened when they 'crashed' the old machines and generated feelings of endings and beginnings and life and death. Turkle specifically referred back to Piaget's theories in relationship to children and the computer 'computers offer an experience of restoring life as well as ending it' (p. 22). Turkle reported that strong emotional feelings were associated with children experiencing computers. They were smart machines. They were alive. There was excitement at responding to a living machine. She also reported the particular view children have of the concept of aliveness of objects. In Piaget's terms, at six a child might see a rolling stone, a river and a bicycle as alive because they move.

The notion of life was built on the concept of motion. For an eight year old child, the river may still be alive because the child cannot yet account for its motion as coming from outside itself, but the stone and the bicycle are not alive. At different stages in a child's development trees could be alive because their branches wave, not alive because they stay in the same place, and alive again because they grow or because sap flows in them. Objects around them were things to think with, for example, the evolution of motion as life developed as children 'play' with the stories of 'the man in the moon', and only later understood the scientific explanation.

However, having pointed out the similarities between a child's relationship to things and a child's relationship to a computer, Turkle considered whether computers had muddied this ordered and evolutionary process. A computer was now highly interactive and contained movement and this confers life. A child will say 'No, the computer is not alive', but a second later will say 'Yea, it can think!' Turkle also referred to Piaget describing how children occasionally use talking as a reason for believing something to be alive.

So far as traditional educational sources infer that a child related to the computer in similar ways to ordinary activities, even to the extent of accounting for why children were observed talking to computers, Vygotsky (1978) also provided a traditional educational explanation of the way children joyously tried all the keys buttons and icons on a computer with zeal. He referred to the natural process of 'try it and see' process of learning through activity. He reported how children did their selecting, while carrying out whatever movements the choice required. His experiment used a keyboard. Children were required to identify each one of a series of picture stimuli assigned to each key. The adult process of internal decision-making was present, but appeared as a series of tentative interrupted activities. The tentative movements were part of the selective process.

The value of Vygotsky's observations has significance to the argument if the traditional keyboard and visual stimulus experiments at the time were assumed to be transferable to current computer interaction situations. There was a precedent for the assumption. Leventhal et al.,

(1994) reported just such exploratory behaviour in hypertext operations with a child at a computer, though the suggested reason was because 'children did not have as complete understanding of card catalogue concepts as adults' (p. 27). They also reported a preference of children clicking on an animal icon to navigate instead of a logical structure defined by the designers. They suggested a tree hierarchy to solve the problem, though their experiments showing how children dropped this search strategy as they became experienced with the program.

In the contextual research children were observed talking to the computer as they carried out activities. Vygotsky described an experiment to show how transfer of attention from one location to another involves hand and eye moving in unison demonstrating a synchronicity between movement and perception. His experiments showed 'the fundamental tie between speech and child's activity' and echoed Piaget's observations. When children were confronted by a complicated problem, they tried to attain their goal by talking to the object itself, talking about the problem, or talking to the person in charge.

Interpreting Vygotsky's findings in a modern context: children using a new CD-ROM for the first time or understanding interfaces and icons (signs) should be expected to 'fiddle around', but the 'fiddling' has meaning and making some mistakes was part of the process and does not show a lack of intelligence. Trial and experimentation was an inherent process of learning for the child in this age group. That children should read the documentation and follow teachers' instructions was desirable, but it was an adult expectation.

In terms of physical activity, Vygotsky also considered children's development to be related to the control by using signs and tools. Gordon (1978) discussed Vygotsky's view of the ability of children to memorise and employ signs as shortcuts in memory. He reported that sign-using activity in children was neither simply invented nor passed down by adults, but was the result of small stages of mind and body activities. Children (between four and six) turned upside down a symbol (a bench) till the sign physically resembled the seat whilst repeatedly speaking the word. Memory processes appeared to operate like a knot in a handkerchief making signs an integral part of recalling events and external objects. O'Hagan and Anderson (1989) defined different kinds of software in terms of first, closed systems that required more explaining and second, open systems that created opportunities for more assessing and taking stock of progress discussions. Improvements in design were proposed with future use of manipulation techniques (as yet unspecified) so children could examine the effect of their behaviour.

The evidence in this section proposed activity at a computer not just being similar to everyday learning opportunities, but that manipulation of objects was an integral process of learning. Learning activities on a computer could be more meaningful if manipulation was employed. A computer mouse had been used as a point and click device, manipulation being confined to system operations, such as moving windows around and carrying out drawing activities in particular graphics software. These findings informed the Research Tool which makes extensive use of manipulation techniques using the mouse for learning activities. The educational value of manipulation seems clear but there were problems.

There were those who were highly critical of the way a computer forces a child to relate to it. For Setzer (1989), the physical involvement using joystick and mouse were considered to be, 'exactly defined computation steps' (p. 10), and are defined as, 'input devices'. Setzer viewed the mechanical, mathematical and abstract operation of the CAL computer GUI designs of the time as the antithesis of the Steiner approach to education. The Steiner approach offers an evolutionary and holistic learning process of a child beginning by participating with whole body developing through interaction with nature, to a being with 'conscious introspection capabilities'. Yet even here the Steiner concern with the whole body and natural activity has a sympathetic resonance with manipulation techniques in the Research Tool.

Crook (1992) reported that pre-school and children in the first three school years had no problem in co-ordinating hand-eye activities to control a computer mouse, though the study was limited to specially designed activities not used in commercial products. There was a conceptual dimension to children using the mouse. However, Crook observed 'children insisting on pointing the mouse in the direction of the arrow on the screen despite repeated guidance and assistance from adults' (p. 206), a feature also observed by the researcher during contextual research. During early trials of the Research Tool children found difficulty moving objects long distances across the screen, an operation that required the mouse to be lifted up to maintain control of the screen object. Small hands had difficulty grasping the mouse. To solve the problem informed by the literature review the researcher redesigned the screen's artefacts so children had only to manipulate objects for smaller distances.

Finally, in relation to Figure 3.9 showing three children at a computer, what do educational writers have to say about group activities at a computer? Anderson et al., (1992, p. 235) saw Piaget and Vygotsky providing clear empirical evidence for the importance of peer interaction in learning as a stimulus to cognitive growth, which might appear to support the value of two or three children working at a computer. However, evidence about two or three children manipulating objects together at the computer was not available, nor has evidence been found concerning issues of angle of view for a group of three children at the computer. Sewell (1990) only referred to the benefits of computers to promote cognitive development in software classified in terms of user control – user control meaning instructional programs using drill and practice techniques. Direct manipulation with a mouse was considered at the time to involve prohibitively complicated and expensive programming. The features of the Research Tool using mouse manipulation were informed by the idea of 'manipulation to enhance learning'.

The section of the literature review on mainstream writings on learning theory was relevant to the study in two aspects:

1. Research pointed to the significance of manipulation and physical relationship with objects in learning processes and informed the Research Tool design.
2. There were no direct references to the importance of optimum viewing conditions, or head-down conditions in learning. However, it was confidently construed that the

research experiments by Piaget and Vygotsky were exclusively carried out in head-down state of body posture whereas in many instances in school, activity at a computer was carried out with children looking head-up at computer screens. The element of optimum viewing conditions was outside the scope of the main study but observations inform the discussion in chapter 6 and conclusions in chapter 7.

The previous sections concluded a series of detailed investigations into visual, emotional and physiological aspects that may improve the quality of engagement in the Research Tool design. These previous sections, each provided challenging evidence for re-evaluating the nature of child-computer relationships. The wider context of metaphors used in interface design was now considered in the next section.

3.3.6 The role of metaphor in interface design

In the contextual research the following observations were made:

1. Pupils appeared to have difficulty navigating or finding their way around the software, instead becoming 'lost' in the multimedia activities, and expressing their displeasure by going off-task and showing anxiety.
2. There was the difficulty of children recognising the meaning of icons and the role of lettering and colour.

Metaphors had a particularly significant in an educational context. This was because, as indicated in 3.2.2, CD-ROMs in the contextual research were and in many cases still are based on the metaphor 'book' *(p. 65)*. The previous sections of the review questioned the visual relationship of the reader to the metaphor 'book' in a physiological context of a computer user and a computer. The argument moved to challenging the understanding of metaphor particularly the 'book' metaphor for the reasons above, but also the 'navigation' metaphor. For the metaphor 'navigation' was very frequently used by interface designers of multimedia products and was an issue for children using CD-ROMs. The challenge to the conventional use of metaphor in interface design was in a cultural context – the Anglo-American philosophic and linguistic tradition of metaphor. The review focused on experiential metaphorical concept theory as described by Lakoff and Johnson (1980). The theory has since been developed further

(Lakoff and Johnson, 1999) to include cognitive science, neuroscience and philosophical views of metaphor. A deeper dimension was proposed for the role of metaphor in human-computer relationships because the early evidence from Lakoff and Johnson indicated the involvement of the physiological elements reviewed in earlier sections of the literature.

Before the cultural aspects were considered the next section examined the tendency for interface metaphors to have been applied superficially – as linguistic concepts. First, sources of metaphors and their application to the computer interface design were described in a broadly chronological and evolutionary structure. Second, the process was traced by which others including psychologists specialised in creating rules for interface design and may have applied metaphors in a superficial manner in doing so.

The evolution of screen design metaphors

The role of metaphor in screen design had its origins in the traditional sense of something which was noticed by the reader as a metaphor. For example, 'his mouth felt like old socks'. Metaphor was defined in this context as a literary construct, a figure of speech. The success of a metaphor was the extent to which comparisons help understanding often through humour and sometimes failed when the metaphors were mixed.

The principles of metaphor had been applied to interface design following its application in other media, notably television and graphic media. For example, the application of metaphor in conventional (literary) media was well established in advertising. Fiske and Hartley (1990) analysed the relationship of metaphor to visual media in terms of icon and metonym to create a system of logical and aesthetic codes. They provided the example of *the mother* in a TV advert as a metaphor of love and security and a metonym of maternal activities. Fiske and Hartley's hypothesis of the 'bardic television' story metaphor for the structure of programmes also did not transfer easily to new media. This was because conventional story structure was broken up, the elements were available at the whim of users and not under the guidance of the storyteller. However, Mountford and Laurel (1990, p. 104) in a survey of the implications of computer games for computer interface design suggested that children developed a new literacy as a result of interactivity.

In the field of graphic design, according to Johnson et al., (1989), Tufte (1985) was strictly graphical information design was significant because his understanding of metaphor was often referred to by new media interface designers, particularly the first Xerox interface designers. Tufte described what may happen in conventional media if there was poor design in visual display. This caused users to be engaged in a verbal exercise, in effect an internal dialogue. 'The visual image flowed through the verbal decoder initially necessary to understand the graphic' (p. 153). Tufte provided evidence of the continued literary tradition even in the area of visual design. However, he gave a prophetic warning when he suggested that multifunctional graphics create 'graphical puzzles with encoding that could only be broken by their inventor' (p. 139). No explicit references by new media designers to Tufte's internal dialogue issues have been found.

Metaphor was represented visually in physical form, by diagrams, shapes and colours by semiologists such as Bertin (1983) who considered visual order to come from value perception. For example, there was an order to perception based on a listing of codes, shape, orientation, colour, value and size. However, Boston (1935) suggested a source of rules of legibility for representation from a visual viewpoint. For example there was only one possible *path* to go from one point to another was a tree. Later Naylor (1966) employed the tree metaphor in the context of early computer development 'There should be a list of actions possible, with added conditions and corresponding results and tree diagram structures illustrate the flow of events.' He proposed knowledge of structural design was essential to multimedia design.

The large-scale computer systems, with their knowledge engineering arising from the scientific tradition, preceded the popular PC multimedia developments in interface design, and appeared to have had no place for metaphors. They were not needed. It was only later that less-intellectual minded users of the popular PCs needed metaphors to lower the cognitive overload.

Browne (1994) used a task-analysis approach for the early large-scale systems. Johnson (1992) wrote before the interactive graphical user interfaces in current CD-ROMs were created. Metaphor did not appear in his approach either. He defined interface design in terms of the system operations.

It was Gardiner and Christie (1987) who illustrated the increasing role of the cognitive psychologists in interface design and proposed effective human-computer interaction relied on users being able to develop an accurate mental model of the way system functions. Eberts (1994) used metaphors in conjunction with analogy:

> Metaphors and analogies are an important kind of learning used quite often in teaching. In teaching the instructor chooses some concrete situation with which the student is familiar and presents new information in terms of how it relates to the old, familiar information.

and

> To incorporate a metaphor the user must be able to apply the old, familiar metaphor. (p. 208)

The role of metaphor took on a different aspect when the graphical interfaces appeared. Analogies arose of 'clearly defined routes' and how users should be able to 'move around easily'. Information should be 'oriented' information at the 'top' and 'bottom' of the screen. Eberts (1994) reported the origin of the 'window' metaphor to have been first proposed by Mayer in 1975:

> Mayer told the subjects that: computer input was similar to a ticket window, output was similar to a message pad, control systems were similar to a shopping list with a pointer, and computer memory was similar to an erasable blackboard. (p. 218).

Theoretical justification for using metaphors in abstract models was suggested by Carroll et al., (1988). They reported that spatial metaphors worked very well. However, Tognazzini (1992) questioned people's process of recognising mental models as incomplete and people's inability to use them limited through forgetfulness and lack of firm boundaries. He challenged the cognitive psychologist's abstract model approach suggesting conceptual models of computer systems should be kept as simple as possible and instead proposed a kinaesthetic model where user's physical actions directly manipulated the interface objects.

The nature of the limitations in the use of metaphor in an abstract scientific model of cognitive psychology identified by Tognazzini was explored further and the possible reasons for the limitation explained in detail in the next section by considering the experiential metaphorical concept theory of Lakoff and Johnson (1980).

The Experiential Metaphorical Concept

Lakoff and Johnson questioned the Anglo-American philosophic and linguistic tradition of metaphor. Lakoff and Johnson's (1980) definition of metaphor as 'understanding and experiencing one kind of thing in terms of another', appears simple. However, they stressed 'In actuality we feel that no metaphor can ever be comprehended or even adequately represented independently of its experiential basis' (1980, p. 19). They considered metaphor as primarily a matter of thought and action and only derivatively a matter of language. The primary claim of their position was that metaphors were not arbitrary, but instead were a natural outgrowth of the manner in which our minds are constituted. They stressed the concepts that occur in metaphorical definitions were those that corresponded to natural experience. They offered human concern to be primarily with physical orientations, objects, substances and seeing. Furthermore these concerns sat within overriding 'container' metaphors of the natural world:

> We are physical beings bounded and set off from the rest of the world by the surface of our skins, and we experience the rest of the world as outside us. Each of us is a container, with bounding surface and an in-out orientation. (p. 29)

'Container' metaphors were ontological metaphors that help with orientation – up-down, front-back. The container metaphor did more than that also defined our ways of viewing events, activity and emotions as entities and substances (p. 25). Ideas became entities – objects. So it was possible to say "I pressed the computer key and got *the solution to my problem*", where the solution was an object. Also using the Mind as a Container (a machine) metaphor for example enabled us to say I "can't *get my mind round* this computer program today."

The significance of container metaphors to the thesis was that Lakoff and Johnson identified the physical relationship between the user and the computer in one inclusive concept – the container and the visual field – in effect subsuming the visual field container within the mind as container:

> We conceptualise our visual field as a container and conceptualise what we see as being inside it. Even the term 'visual field' suggests this. The metaphor is a natural one that emerges from the fact that when you look at some territory (land, floor space, etc.), your field of vision defines a boundary of the territory, namely, the part that you can see. Given that a bounded physical space is a container and that our field of vision correlates with that bounded physical space, the metaphorical concept, visual fields are containers emerges naturally. Thus we can say, 'The ship is coming into view.' 'I have him in sight.' 'I can't see him the tree is in the way.' 'He's out of sight now'. 'That's in the centre of my field of vision'. 'There's nothing in sight.' 'I can't get all of the ships in sight at once.' (p. 30)

Lakoff and Johnson acknowledged the ecological psychology of Gibson (1986) and the tradition of research in human development of Piaget (1952), drawing together in their theory an integral relationship of the 'visual field' as a container within which objects can be directly manipulated (p. 70) as part of the learning process.

The Macintosh Human Interface Guidelines (Apple Computer Inc., 1992), acknowledged the significance of Lakoff and Johnson, defining metaphors in the context of:

> You can take advantage of people's knowledge of the world around them by using metaphors to convey concepts and features of your application. (p. 4)

However, at issue here was that Apple system interface designers might have not comprehended the wide and pervasive effect of the experiential metaphorical concept. The computer's internal metaphors were still conceived as relating to external 'intellectual' knowledge. Apple metaphors employed 'concrete familiar ideas' (p. 4). The example was used of hard disk files and folders, which were 'analogous to the way people organise their filing cabinets' – note the use of analogy – again a literary form. An important point was that these were guidelines to the operating system only, not to the later multimedia products, as these were not yet in production. The Guidelines considered Lakoff and Johnson's work as:

> A delightful book that discusses the ubiquity of metaphors in language. The book makes the point that metaphors are not so much picturesque uses of words, as systems of concepts that affect how we describe, think about and experience the world. (p. 4)

The use of 'analogous', 'system of concepts', 'describe', 'think' and 'experience' also focussed on the superficial qualities of the Macintosh operating system rather than the deeper, interactional advantages of manipulation which the operating system incorporated. The difference was subtle but vital. Lakoff and Johnson themselves may have distracted new interface designers:

> We feel that objectivism and subjectivism both provide impoverished views of all these areas because each misses the motivating concerns of the other. What they both miss in all of these areas is an interactionally base and creative understanding.
> (p. 231)

Lakoff and Johnson's view was that the origin of the limited, linguistic interpretation of metaphor lies in the expression of the Anglo-American philosophic and linguistic tradition that developed as an adjunct to scientific thought and particularly the need for a descriptive language. In the process of creating a separate literate description of events, the human involvement with the environment has been divorced from the physical experience:

> The traditional view of metaphor has been treated as a matter of language rather than a means of structuring our conceptual system and the everyday activities we perform. The idea that metaphor is just a matter of language stems from the view that what is real is wholly external and independent of humans – this is objective reality but leaves out human aspects of reality that matter to us. There is no such thing as metaphorical thought or action. (p. 153)

That the new multimedia groups of experts coming together to work on the new multimedia software challenged these original science and art cultural boundaries was conjecture. However, Mountford and Laurel (1990) reported that there were language problems and conflicts between the 'new' and 'old ' elements of the design team; that was the graphics design and the programmers. Both had expectations of users' familiarity with their own areas of knowledge and were exasperated by users' ignorance. In other words metaphor was being used in the context of a new, complex production process combining science and art skills. The result – the user interface –was to be judged by the user, according to Mountford and Laurel 'If an interface does not meet the user's need then it doesn't matter about the design' (p. 54). They proposed the user interface should assist the user by employing the metaphor of an ambassador, pen pal, or tour guide. However, Mountford and Laurel appeared to use the metaphor 'guide' incorrectly in Lakoff and Johnson's terms. For Mountford and Laurel a 'guide' was a literary metaphor. It was not an experiential metaphorical concept; it was an abstract concept. The 'guide' might be an experiential metaphorical concept in Lakoff and Johnson's sense only if the 'guide' could be physically manipulated by the user – moved round the screen by the mouse – and might even physically 'guide' the user by 'taking' him/her into folders by clicking and dragging featuring the manipulation and interactive physical experience of a guide. Mountford and Laurel's pen pal only sat at the edge of the screen and gave verbal instructions, such was the constraint of programming at the time.

A final example was provided by Erikson (1990) of the limited and superficial cultural interpretation of interface design metaphors in his account of the construction of the HyperCard software. HyperCard used the 'card' metaphor but effectively the result was a 'book' with 'pages'. Erikson criticised the physical element of the page changes, which disappeared instead of using a visual form of page turning. However, Erikson, in common with the cognitive psychologists described above, perceived metaphors functioning as '...natural models that allow us to take our knowledge of a familiar object and event and use it to give structure to an abstract, less well-understood concept' (p. 73).

One of the major multimedia interface design metaphors employed has been the metaphor 'navigation'. Because the contextual research showed children having particular problems with 'finding their way round' CD-ROMs the issue of navigation was investigated in greater detail.

The Navigation Metaphor

This section was a case study example of the metaphor 'navigation' re-evaluated in the light of Lakoff and Johnson's theory, and illuminated further the general issues outlined in the previous section. It was a chronological description of the evolution of navigation in the context of that development culminated in suggesting the possibility of an improved metaphorical model as a three-dimensional construct within a higher order 3-D navigation metaphor – 'container'.

The navigation metaphor was arguably the most quoted and discussed interface metaphor, and was important in terms of computer operations. It was used in several contexts. For example navigation formed a key element in the design of a multimedia product, as authors' structured a user's experience of the product. Also users described the process of navigating their way round the product. Writers described the multimedia product operations in terms of difficulty or ease of the process of navigation.

The navigation metaphor was not a new concept. For example, it had a literary tradition in 2-D text as in Figure 3.12. Chapman (1987) used chaining, register, cohesion, ellipsis, conjunction, and co-location.

> "Let' start at once, said Roger, but at that moment
> the kettle changed its tune.
> It had been bubbling for some time, but now
> it hissed quietly and steadily, and a long
> jet of steam poured from its spout.
> The water was boiling, Susan took the kettle
> from the fire, and emptied into it a small packet of tea.

Figure 3.12: Trails of connectivity between key word themes. (Chapman, 1987, p.93)

Chapman measured the quality of reading texts by physically drawing 'routes' through text. Relational lines between key words in a story are 'mapped'. Text with continuous lines of communication through a paragraph was easier to read – more easily physically navigated by the human eye. Eco (1994) showed the physical relationships between elements of a story represented in 2-D 'container' diagrams as in Figure 3.13 below.

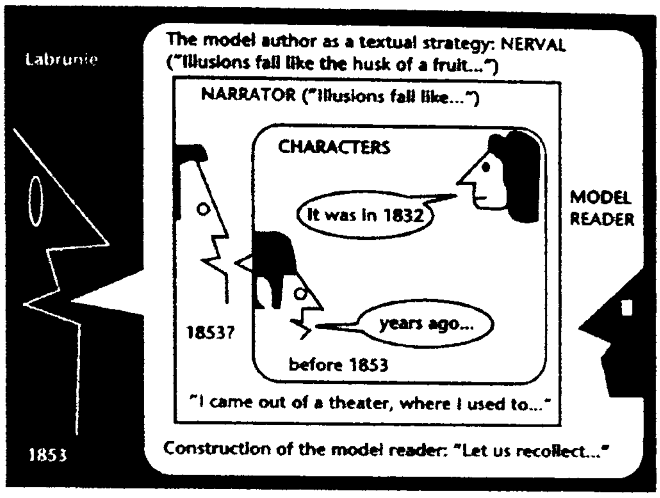


Figure 3.13: From 'Entering the woods'. (Eco, 1994, p. 21)

Campbell (1988) identified how in any story there was a journey with navigation as a process and a universal metaphorical element. His work, which was first published in 1948, drew on historical texts, but recently his analysis has been popularised and applied to films such as *Star Wars*. He identified the elements of a quest – a hero, a mentor or guide, a journey and a goal, death – and defining moments were shown to be consistently evident in a comprehensive view of learning in life. Campbell's argument was more comprehensive than that proposed by Laurillard (1993) in an educational environment in terms of a cyclical teacher and learner relationship, or in a computer context by Mountford and Laurel (1990) who defined the metaphor 'life as a stage'.

'Routes' and 'journey' navigation metaphors exist in audio terms too. An example from the *Starcatcher* script in Figure 3.14 was used based on the researcher's own experience as a radio producer to illustrate the radio equivalent. The figure shows the journey structure of a typical radio script with the Narrator (Robert) introduces the subject and provides factual information. The sound effects (FX/Music) provides a transition or bridge giving an audio clue carrying the listener to a fictional 'place' emphasised with a magical sound effect (FX: shooting star). The narrator intervenes again with factual material, in this case ideas how children can sing a song. The listener is guided on a journey and navigates the story with audio signposts that are recognised by children through experience.

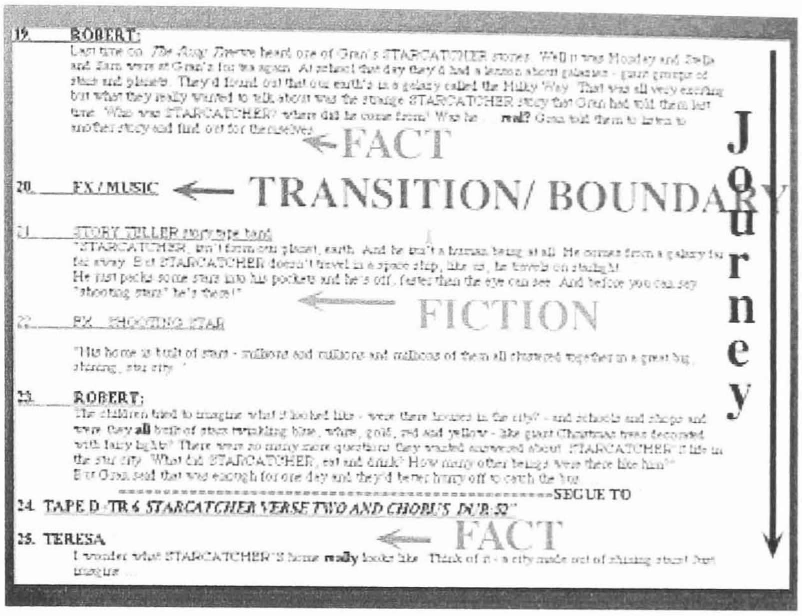


Figure 3.14: Diagram: A visual representation of how the metaphor ' navigation' operates in a conventional children's drama script. (Howarth, 1995b, p. 5)

In a radio production there were also navigation metaphors of: a good 'beginning', two or three 'high points', at most five key teaching features, and a good 'ending' in a radio production. Features of all effective education broadcasts were; a narrator who told users what they were about to learn, a 'transition' sound effects (FX) or music to set up the example – typically a drama fantasy illustrating the point, there was a return, via a transition, to the real world – the narrator – and a repetition of the teaching point. The switch from real world to fantasy world placed in a radio script was 'navigation' – an audio 'journey in 2-D'. The journey did not work with quick jumps (except in moderation, to attract the listener's attention). It was the slow, musical bridges or sound effects which helped users' navigate their way take along the journey. The navigation metaphor in education radio deserves a much deeper study than was possible here.

The argument looked next at the evolution of the metaphor 'navigation' in interface design itself. It has already been argued that the navigation metaphor has a tradition in earlier forms of media. In the evolution of new media, the first developments of the metaphor 'navigation' were in the hands of the software programmers. For example, Johnson *et al.*, (1989) reported how the 8010 STAR was first conceived in 1975, Xerox PARC having been established in 1970. But the story really started in 1945 when Bush envisioned a desktop device called MEMEX. Sutherland built Sketchpad in the 1960s. The first system to organise navigation of textual information in trees and networks (which developed separately as hypertext) was developed by Engelbart in 1968 who also invented the mouse in a system called NLS. Later the techniques were incorporated in a reactive engine created by Kay containing the seeds of many ideas that were picked up and used in STAR. Kay later developed Smalltalk, a language for object-orientated programming. Navigation using a hierarchical visualisation of content was in commercial development by 1989 with a system called Treemap using the tree metaphor. It was originally a game, later made available in ViewPoint hardware by Xerox and released as PC compatible (Canfield Smith, 1982). It was absorbed into Windows software in the file manager system. Hypertext emerged as a commercial product called HyperCard and exists today in a much-evolved form as HyperStudio.

Navigation using physical manipulation techniques was the subject of further experimentation. Using a co-operative manipulation metaphor by Taylor et al., (1991) described the use of a computer glove as 'exotic' (p. 6) preferring a conversational metaphor of 'dialogue' be used. Clarkson (1991) described how Xerox PARC Information Visualizer 'is going to appear in the next 5 years' using metaphors such as to 'browse files', 'browser', 'people browser'. The Visualiser also used 3-D rooms with perspective walls and multiple workspaces. The tree was a cone-shaped hierarchy of files. Navigation included the manipulation of information with the mouse, which took place while walking, touching walls and changing rooms and picking up objects. The wall slid round like a sheet of music on a 'player piano'. Despite featuring many of the ideal elements of a modern graphical user interface the 3-D Information Visualizer was not developed as a commercial product because of its high computer memory requirements. Instead the less memory hungry two-dimensional hypertext software was chosen, based on the property sheets or pages of the STAR system. Smeaton (1991) suggested lack of consensus to old and new media solutions to the navigation metaphor:

> Many solutions to the problem of navigation have been proposed, some of which exploit human spatial processing abilities by representing the hypertext in a 2 or 3 dimensional space with maps, landmarks, compasses, while other methods employ the navigation tools used in traditional printed media like bookmarks, annotations and thumb tabs.
> (p. 173)

And there was always an awareness of the limitations of navigation in two-dimensional features of hypertext as Smeaton states:

> However, such a structure can present problems when navigated by users who can easily become lost as the *topology* of hypertext is monotonous and lacks guiding features. (p. 173)

Lipner (1994) indicated possible implications for gender differences in human-computer interaction strategy preferences, with reference to computer display navigation:

> Differences in the way in which males and females navigated were also suggested, but these gender differences were found only in the complex conditions. Males used constructive or global strategies whereas females used analytic or sequential strategies to navigate. In contrast to males, females deviated more from the direct path, were more disoriented and did not internalise the information space. Collectively, these findings demonstrate that strategy differences play an important role in determining users' spatial behaviour in electronic information space. (p. 214)

Leventhal et al., (1994) reported on age-related differences in the use of hypertext:

> While adults were superior to children in speed and accuracy, there were no indications that children were qualitatively different from adults in navigating patterns or perceptions of the system. Some children exhibited more exploratory problem solving behaviours than adults did. (p. 19)

There were other navigation metaphor issues reported. Hypertext was known to cause disorientation as discovered early on by Conklin (1987). Norman (1994) referred to the term hypertext, first coined by Ted Nelson in the 1960s as meaning 'vast and far-reaching' (p. 36), but hypertext had since come to mean 'fast and frenzied' and not conducive to education, because 'It is capable of creating erratic jumps both within and across vast domains of knowledge' (p. 37).

One solution was a program called EntryWay as illustrated in Figure 3.15, that maintained a history of visits to each hypertext node with 'trails', 'nodes', 'links' and map 'threads' to allow users to 'track' where they had been. Horney (1993) expressed reservations about the diversity of navigation in hypertext and called for a coherent study of what readers do and when they do it using the EntryWay's visualised results. The visualisation was a pseudo 3-D perspective image *(Figure 3.15).* The researcher proposed that the pseudo 3-D visualisation gives a far clearer indication of the overall route to be 'navigated', 'places visited' and the relationship between the two, than the usual menu page as illustrated by the drop down menu list of pages and subjects.

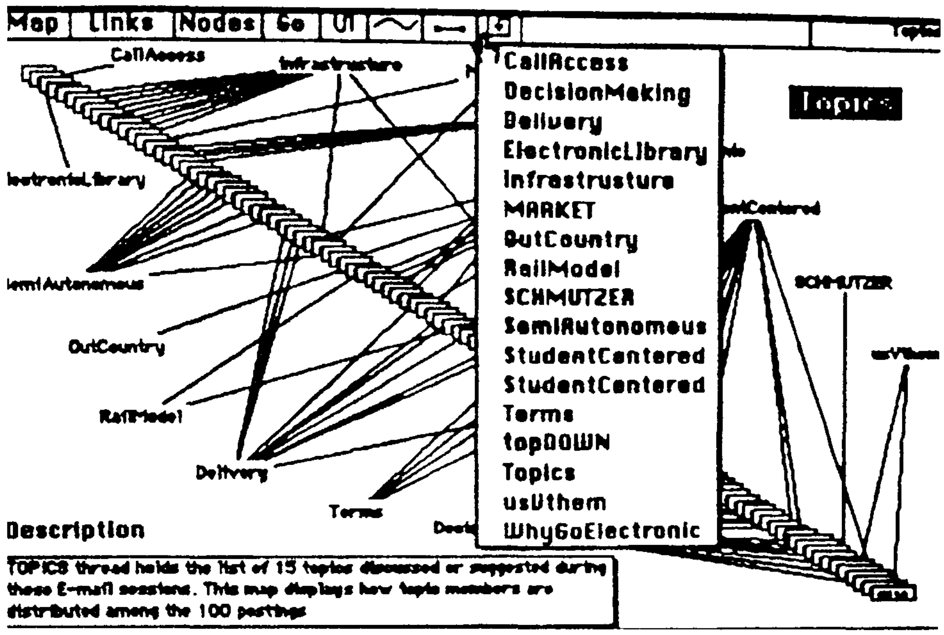


Figure 3.15: A map of threads showing the connections between postings of different file cards. Created by the EntryWay software. (Horney, 1993, p. 259)

Lakoff and Johnson's (1980) 'navigation as container' informed the value of the pseudo 3-D visualisation in the Research Tool as indicated above. This was because they defined the relationship between routes, journeys, information and argument with container terminology because more 'surface' was created, as in Figure 3.16.

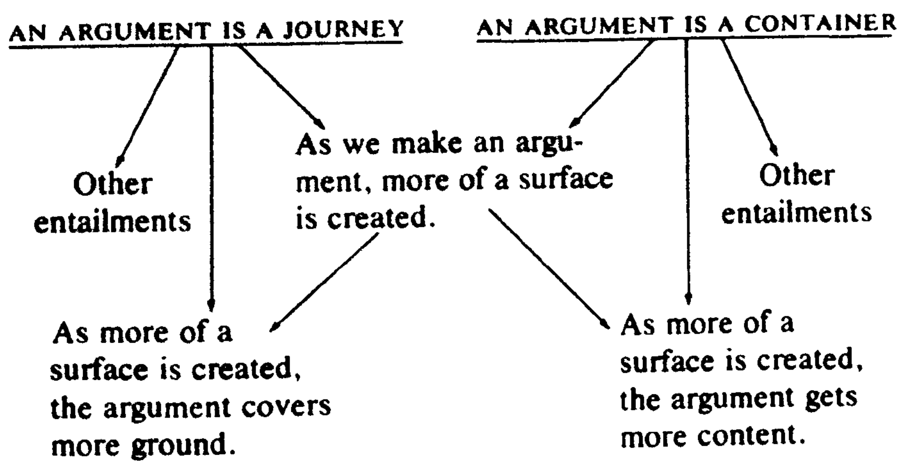


Figure 3.16: The relationship between more route, journeys, information and argument surface and the metaphor container. (Lakoff and Johnson, 1980, p. 94)

It was proposed that the EntryWay illustration with its pseudo 3-D perspective properties in Figure 3.15 was an example of the visualisation of more 'surface' being conceptually experienced by the 'container' metaphor mapped out in Figure 3.16. As a result, an argument has more content as in pseudo 3-D visualisation and, in an educational context, potentially but not necessarily, a richer learning experience.

The significance being drawn between Horney and Lakoff and Johnson to the argument in this literature review was due to the following relationships: evidence of the values of greater depth and quality of engagement when children use computers came from the visual search and ergonomics elements of the literature review; interface designers have superficially applied the metaphor 'navigation'; Lakoff and Johnson have demonstrated the deeper, physical, experiential aspects of the metaphor 'navigation' in a 3-D; the value of manipulation during learning has been demonstrated in the section on educational theory; manipulation that happens naturally in a 3-D environment. The conclusion was that there was a logical argument for children, indeed adults finding 'navigation' and learning processes more comprehensive if physically involved in some form of 3-D interface design – even in pseudo 3-D perspective – as illustrated in Figure 3.15. Many researchers have confirmed the value of 3-D environment but the argument proposed here was for a logical relationship between existing software and hardware configuration problems in an educational context.

Finally, educationalist writings did not consider the issues described by Held (1974) who demonstrated the visual field of the human as a spherical 3-D field of view as illustrated in Figure 3.17.

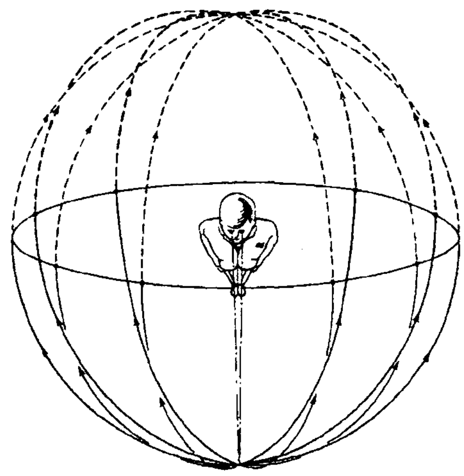


Figure 3.17: Diagram: The directions of deformation in the Visual Field during forward locomotion as projected on a spherical surface round the head (Held, 1974, p.123).

Held drew from Gibson's (1986) ecological interpretation of the flow of visual information in 3-D, represented by the arrows across the surface of the eye radiating out from a central position. The flow causes distortion of the visual image. Also the only object in focus at any one time was a small area at any point on the sphere. It can be inferred that busy children moving their head and body using the computer in less than optimum viewing conditions would be subject to these distortions of view.

However, Held's physiological findings considered in conjunction with Lakoff and Johnson's linguistic research combined to conclude the argument; a proposal that the physical manipulation of navigation in a spherical-shaped container of three dimensions was physiologically and conceptually more efficient. By inference pseudo 3-D interfaces could contribute to a more effective educational computer environment especially when the navigation 'tool' was the mouse physically manipulated by the user.

Restating the main argument; if engagement was physiologically deeper and visual clarity more efficient when users look down; when learning benefited from manipulation of objects; if pleasure included manipulation and concentration; if metaphorical understanding included three dimensional concepts; then the creation of human computer configurations and interface designs that took into account these factors were likely to enhance the quality of learning at the computer.

Earlier in the literature review problems with interfaces which used the metaphor 'book' were discussed. In the next section a proposal that a screen 'book' metaphor using a pseudo 3-D perspective interface may be conceptually more effective was investigated.

3.3.7 Improving learning using pseudo 3-D perspective interfaces

Earlier in the literature review issues surrounding interfaces which used the metaphor 'book' were discussed. If the value of a pseudo 3-D perspective interface using the metaphor 'book' which gave users a physical and visual sensation of being manipulated even in a pseudo 3-D environment could be shown as logically sound, based on the evidence found in the literature review, then the main argument would have its validity confirmed.

Briefly summarising the evidence already presented; a real book was shown to be held naturally in the orthogonal plane to the reader as in the Mach drawing (Held and Durlach, 1991), Figure 3.7 above. In the natural optimum viewing conditions of a head-down book reader; a reader was aware of where he or she was in the book because of the physical clues such as the tactile responses of the relative thickness of the pages in each hand as well as visual clues including perspective on a page.

The situation of a reader of a 2-D computer screen flat representation of a 'book' was quite different. The reader was in the head-up position on most school computers. Physiologically inefficient, the interface using the metaphor 'book' or 'page' presented in the vertical plane had specific problems associated with it; the computer page was nearly vertical, a reader's head was held at a near horizontal viewing angle. Literature reviewed described the stress associated with the horizontal viewing angle of the head and lack of agreement by ergonomists as to the optimum position of head tilt, and the optimum position angle of the screen sloping away from the reader. As already reviewed Intriligator and Cavanagh (2001) and Sheedy (1990) informed the reasons for the advantages of Cochrane's observations in their studies of features of the visual system. Also in terms of manipulation in the learning process these single and especially multiple viewers have no tactile clues as to the depth and structure of the book and may hardly be aware of their hands and the rest of their body at the edge of their peripheral vision because of the head-up position; the result was similar to the problems of driving a robot vehicle (Held and Durlach, 1991) when the controller reported slow reactions when a narrow camera view did not show the foreground. In addition, the relationship of a child and the screen may vary considerably *(Figure 3.9)* and that not only one child but three may all be looking at the computer with varying vertical and horizontal viewing angles.

Lakoff and Johnson (1980) informed the argument for why the existing 2-D screen HyperCard 'book' metaphor was much less efficient and informed the navigation issues described by Erikson (1990) and problems of children being 'lost in hypertext'. Interpreting the value of a pseudo 3-D metaphor 'book' argument using Lakoff and Johnson's evidence; when they described the conceptual process of greater 'surface' enhancing argument, the 3-D metaphor 'book' was only a conceptually whole experience when an individual related to the book in a 'container' metaphor, and was easier to navigate through when physically involved in the reading activity. A book in the hand – in Lakoff and Johnson's terms of the metaphor 'book' – implied a rich cognitive experience because the book had more 'surface'.

How the pseudo 3-D perspective interface with its greater 'surface' could be created was well-know and relatively easy to achieve. Ellis et al., (1991) proposed the best ways to provide the 3-D visual clues to depth created in a pseudo 3-D environment in 2-D were: overlap, linear perspective, manipulating intervals between greys or colours between objects, lighting, providing shadow especially from the side. Shadows provide information about refractive properties and density of the object. The default lighting was upper left on objects in a simulated 3-D environment. All these features increased the ability of users to acquire information more efficiently in terms of faster recognition times.

The application of a pseudo 3-D perspective interface to the metaphor 'book' already exists in CD-ROM publications by the British Library (2002). The evidence from the literature review suggests that the 3-D perspective interface has concrete, significant value in an educational context beyond an interesting visual technique.

Finally, of especially interest to the education process, Lakoff and Johnson reported that when people could not 'grasp' the situation, when things were 'up in the air', in terms of orientation within the 'container', unknown was 'up' and known was 'down'. Here, the experiential basis was 'understanding is grasping':

> With physical objects, if you can grasp it and hold it in your hands, you can look it over carefully and get a reasonable understanding of it. It's easier to grasp something and look at it if it's on the ground in a fixed location than if it's floating through the air.
> (p. 20)

Lakoff and Johnson were clear about the physical need for grasping knowledge. The inference was that the 'book' held in hand would be better understood. They evidenced the advantageous physical relationship between the natural head-down position and the mentally best position for 'understanding' with a manipulation of information. The language used has much in common with the language used by children describing the advantages of the portable computer (Bowell et al., 1994).

This section demonstrated how coherence existed between physiological vision processes and the metaphor 'book', when metaphor was interpreted as having a physical experiential component. It was proposed that the example of using the metaphor 'book' confirmed the argument that a metaphor using a pseudo 3-D interface could contribute to a more effective educational computer environment especially if the navigation 'tool' was the mouse physically manipulated by the user. The coherence was formalised in the next section.

3.4 A new holistic paradigm

Arising from the evidence presented in the literature review was a proposal for a new coherent holistic paradigm that may enhance conditions for greater depth of engagement between child and computer interface in a classroom. The evidence is summarised in Table 3.2 as follows:

1. Children's eye function, field of view and vision issues

An understanding of children's eye search patterns:

1. How the eye tended to focus on small areas due to the physical structure of the eye.
2. Preference for shapes of text and for edges.
3. Attention was more focussed when objects were moved with the mouse.
4. Looking down and awareness of lower body were natural states for deeper engagement.
5. Children often did not view screens in these optimum conditions.

2. The role of ergonomics and workstation design

1. Human–computer ergonomic standards originated in VDU control-room workstation specifications.
2. The standards for an optimum display angle were a compromise between optimum reading and optimum writing positions.
3. There were unresolved controversies about agreed standards for writing and reading positions at the computer.

3. Pleasure in learning

1. The quality of learning was enhanced by encouraging learning events through 8 criteria (see p. 93), particularly manipulation of objects, which combines enjoyment with activity and results in a deeper form of engagement.

4. Manipulation of objects and conventional education theory

1. The benefit of physical activity in traditional child development was clearly evidenced. The case for a similar relationship in the context of the new media interface design was not apparent in educational multimedia writings.
2. There were no references that have been found to the importance of optimum viewing conditions, or head-down conditions in conventional learning – the supposition assumed this was a natural posture.

5. The role of metaphor in interface design

1. The navigation metaphor existed in pre-computer media.
2. The early use of metaphor was employed as in a relatively narrow abstract model for popularising understanding of interface operations.
3. The metaphor 'container' was a physical 3-D experienced construct.
4. Conventional use of navigation metaphors could be more effective if interpreted as a pseudo 3-D container metaphor.
5. The efficiency of 3-D and manipulated computer environments was acknowledged but the application was limited by commercial considerations.

6. The potential for improving learning using 3-D perspective interface designs

There were no existing guidelines for incorporating 3-D imagery in educational new media:

1. Pseudo 3-D methods made screen interfaces easier to use.
2. Errors occurred when looking at objects in 2-D.
3. Features in 3-D may provide faster visual search
4. British Standards of viewing angles may be questioned.

Table 3.2: List of features encouraging greater depth of engagement and coherence in interface design for educational purposes.

The evidence summarised in Table 3.2 described a set of features which might enhance engagement: visually clear easy to follow interfaces, simple navigation, audio instructions, manipulation of objects, humour and enjoyment, small changes in tasks, an increased complexity of tasks, and discussion. Essential, but once removed from these features, due to technical aspects and external factors are the value of a pseudo 3-D perspective interface and the optimum desk and screen configuration. The new holistic paradigm as a framework describing the conditions for a greater depth of engagement was aided by the synchronicity of the container metaphor and its spherical human field of view boundary.

The potential value of pseudo 3-D perspective interfaces in the new holistic paradigm arose through showing the integration of the visual field of the child within a physical 3-D container of body awareness, which was itself a conflation of the physical and linguistic elements of the container metaphor.

The redefinition of the height and viewing angles of a computer screen might enable the full advantages of the 3-D container to be optimised. These optimum viewing conditions cannot be achieved by interface design alone and, though they can be applied within current classroom conditions require a programme of training for staff and students.

The evidence of the literature review informed ten features of an improved interface design that forms the new holistic paradigm. These ten features guided the design of Research Tool interfaces. Some of the features meet current accepted standards, such as clarity of instructions and tasks, and ease of navigation, but are qualified in the light of evidence in the literature review. The Research Tool also included, potential 'higher' specifications – qualities that arose from drawing together a range of disciplines studied in the literature review. The choice of these features was subject to the limitations imposed by the production schedule, costs and the software as for example the pseudo 3-D element. Table 3.3 is a list of the ten improved interface design features.

Currently accepted standards with improvements
1. Clearly defined tasks *but* take advantage of vision issues. 2. An easy to use interface *but* includes one interface – the story – using a looking-down viewpoint to explore unresolved ergonomics controversies. 3. Clear feedback from interface actions *but* actions using physical manipulation so feedback involves a wider range of senses and a greater depth of engagement. 4. Easy navigation *but* take into account advantage of the reported benefits of pseudo 3-D features.
Higher specification arising from the literature review findings
5. The value of enjoyable and absorbing educational activities was formally recognised. 6. An interface activity that engages the user in concentrated activity through manipulation of screen objects. 7. Manipulation of a screen object must be easily achieved by a small child's hands. 8. Interface activities that make small changes in demands on the user. 9. Activities should have elements of multi-functionality that are absorbing but do not cause confusion. 10. A teacher should be able to control the organisation of children's use of the software.

Table 3.3: List of ten improved interface design features for investigation in the main study.

The ten features will become the subject of the main study and in chapter 4 and 5 will be formulated as ten criteria used to evaluate four core components of interface design: the design and screen layout, the audio instructions, the actions involving the movement of objects with the mouse, and the control panel. The analysis of the results will then inform the research question: **What are the design features required to improve the quality of computer interface interaction for 5 to 7-year-old children?**

The relationship between the wide range of subjects reviewed and the ten features that enhance the depth of engagement and form a new holistic paradigm are summarised in Table 3.4 to help clarify the structure of the argument.

Ref	The areas of study in the literature review	The ten features of the Research Tool
	Currently accepted standards with improvements	
3.3.2	**Children's eye function, field of view and vision issues:** Visual search patterns are a valuable source that can inform multimedia graphical interface user design guidelines. Children are not viewing the computer screen in optimum conditions.	**1) Clearly defined tasks**, *but* take advantage of vision issues.
3.3.3	**The role of ergonomic and human factors:** Unresolved controversies of human computer design issues. Standards are a compromise to meet known discrepancies between optimum reading and optimum writing positions.	**2) An easy to use interface**, *but* in a child/computer configuration that resolves ergonomics controversies of desk angle.
3.3.2 3.3.5	**Children's eye function, field of view and vision issues:** **Manipulation and conventional education theory:** The significance of manipulation and physical relationship with objects in the learning process was well recognised, if not applied in educational multimedia.	**3) Clear feedback from interface actions**, *but* actions should have a physical/ manipulation component so feedback involves a wider range of senses.
3.3.7	**Improving learning using pseudo 3-D perspective:** The potential role of improving learning using pseudo 3-D perspective interface designs. An understanding of how pseudo 3-D methods can still aid screen design. 3-D increases the speed of recognition. Navigation to use a container metaphor.	**4) Easy navigation** *but* taking into account advantages of downward perspective viewpoint
	Higher specification arising from the literature review	
3.3.4	**Pleasure in learning:** Interfaces which combine enjoyment with activity and a deeper form of engagement (Flow Theory)	**5) The value of enjoyable and absorbing educational activities** was formally recognised.
3.3.4 3.3.3	**Pleasure in learning:** Pleasure in using one's body. **The role of ergonomic and human factors:** manipulation – 'giving the qualitative feeling that one is directly engaged with the control of objects'.	**6) Interface activity through manipulation** of screen objects that engages users in more concentrated activity.
3.2	**IT in primary education:** The negative effect of 'hardware-first' approach.	**7) Child friendly computer desks** and mouse activities easily achieved by a small child's hand.
3.3.4	**Pleasure in learning:** Environments that vary in difficulty level, 'increase both challenge and potential for learning'.	**8) Interface activities that make small changes in demands on the user.**
3.3.4	**Pleasure in learning:** Varying levels of difficulty enhance concentration and enjoyment.	**9) Activities should have elements of multi-functionality** that are absorbing but do not cause confusion.
3.2	**IT in primary education:** Teachers need training in IT across all subjects in their classrooms.	**10) A teachers' control panel** to manage the organisation of children's use of the software.

Table 3.4: Relationship of the literature review to the ten features of the Research Tool.

3.5 Summary

During the period when the literature review was undertaken (1995–1999) there have been exciting developments in interface design. The period was signified by a parallel development in multimedia programming and technology. Lines of code on a black and white screen have evolved to now contain multi-functional graphical user interfaces on full-colour high-powered computers. The literature review took place in the context of this period of rapid experimentation and growth. The rapid growth left areas of concern with significance for the relationship between children and computers in a classroom. The evidence from the literature review suggested a strong case for a new coherence that required a revision of the conventional holistic human-computer perspective. The literature review has also revealed how these areas of concern may be addressed. The proposed ten features may enhance the depth and quality of engagement in a new holistic paradigm and these features were formulated into criteria that informed the research question that the Research Tool is to answer. The methodology design for the Research Tool is now the subject of chapter 4 and the main study is described in chapter 5.

Chapter 4: The methodology

4.1 Introduction

Chapter 4 sets out to describe the methodology for effectively and thoroughly testing the Research Tool. In the process the research question and subsidiary questions are finalised. Chapter 2 described the underlying principles and the process of the creation of the Research Tool. Chapter 3 investigated textual sources to inform the design of graphical user interfaces of the Research Tool and focussed the investigation into ten features that may improve interface design. The thesis can now progress to refining the methodology for the main study. The subject of the main study was an enquiry that sought to understand the way children used the Research Tool in the classroom, therefore the research was qualitative in nature. Several methodology pilots took place and this chapter demonstrates how research design issues were effectively addressed through a reiterative process to ensure validity through a refining of the methods, the way they were combined and how the data was used. The result was a robust research methodology to assess the Research Tool results in the field. There were 3 stages in the process of refining the qualitative methodology for the main study:

Stage 1: The first methodology pilot began very early during the Research Tool testing period. The timing of the first methodology test was determined by the commercial production schedule.

Stage 2: The second methodology pilot dealt with the issues raised by the nature of the Research Tool as discovered during the early software pilot.

Stage 3: The final methodology design was finalised using the experience gained during the two previous pilots.

In the context of this particular thesis the refining of the research methodology included the testing of the Research Tool in Stage 1. However, once the Research Tool was completed the research methods were the only aspect changed during the later pilots. The opportunity taken to test the methodology at Stage 1 both improved the functionality of the Research Tool and gave rigour to the research methodology itself.

4.2 The first methodology pilot

The first pilot took place at a Junior, Mixed and Infants (JMI) school during the production process of the Research Tool in December 1995. This pilot was designed to achieve two aims: to make an initial, informal and general exploration of the form the methodology should take and also to test the initial operations of the software program. Software testing was required by the BBC. The researcher was a parent governor at the school and knew most children by sight. It was the day before the end of term. The computer brought by the researcher with the Research Tool software already installed was set up in the library with the aim of not disturbing classes. The program was used for the whole school day. The method of recording events was using the Sony Minidisc digital audio recorder not video recording for reasons indicated in section *4.6 Use of the digital audio recorder*. Children had some prior knowledge of the project but only in terms of their involvement in creating the audio files for the first draft of the program. Twenty-one children took part; each group of 3 children used the software in turn observed by the researcher and, at the end of the day, the same children now in 4 groups of about 5 children each were interviewed by the researcher in turn about their experience of the software. The researcher observed sitting on a low stool and to one side of the group. In the group interview the researcher sat opposite children arranged in a semi-circle pointing the microphone to each child as they spoke. Groups of three children were chosen because this was the conventional method generally used by teachers in schools. Teachers used this method to ensure the maximum number of children could experience the one or two computers typically available in a classroom at the time.

The observation methodology was changed as the events of the day progressed. The software worked without any technical errors, so the researcher could concentrate on the methodology. The first three observation groups A and B and C were asked just to explore the product. Group A was not given any instruction. Group 'B' was told who Starcatcher was and asked to find out more. Group 'C' was told about the music and aims of the program. Approaches used in Groups 'A', 'B', and 'C' elicited very little response from children. However, Group 'D' was shown a series of work cards that said 'Find out all you can about Starcatcher and tell me about him.' Group 'E' was asked to take part in all the activities and sing along.

It was observed that there was a marked increase in excitement and interest expressed by Groups 'D' and 'E'. The researcher observed that Group 'D' and 'E' children, who used the activity cards, displayed greater involvement in terms of exploration, discussion and time spent on activities. However, children had some difficulty reading the cards. The researcher modified his approach during the sessions with Groups 'D' and 'E'. Realising the potential of audio instructions appearing on the activity pages within the software, the researcher began to test the potential by rephrasing the Group 'D' instructions cards and reading them to children as clear verbal instructions to Groups 'F' and 'G'. The researcher asked all children in the new Groups 'F' and 'G' to, 'Sing along and take part' in the activities. The observation was that children's involvement was more immediate, more interactive and focussed. Including this observation, there were four important observations:

1. The researcher could see the Research Tool was too open-ended and children needed more guidance but that the guidance could be made independent of an adult by using the audio instructions.
2. At this stage of the development of the methodology the results of the observations were tentative. Listening to the audio recorder playback, the physical activity rather than clicking, enhanced with the sounds and symbols seemed to engage children in a much more creative and enjoyable way. The Research Tool activities required children to manipulate icons around the screen. The icons were sometimes letters, sometimes symbols and also tools such as an instrument beater. Once encouraged by the verbal instructions of the researcher to take part, children could be heard to be spending less time clicking everywhere and took more time moving the icons around. The effect appeared to be to slow down the excitement to a less frenetic pace. It was quite clear that moving icons around was a new task and quite

different from clicking. The activity was exciting to children, but also caused some basic practical problems of making the icons move around. The observation was made that this might be a physical skill that detracted from the task.

3. Children found it difficult to talk about the computer some time after using it. Children would need to be interviewed next to the computer and while using the software.
4. Recording a group of children was technically difficult even with a professional microphone. Interviews should be on an individual basis.

The experience of the first pilot suggested that, as well as the 4 observations described above, the following general requirements should be incorporated in methodology design:

1. The researcher's observations at the computer would need to be verified from other sources.
2. Methods of recording evidence of the research, particularly children's activity at the computer, would be required.
3. Methods of recording the effects of the soon-to-be-incorporated sound instructions and the movement of icons should be sought.
4. A method of standardising the introduction of the program to children and staff would be required.

Changes were made as a result of the first pilot to the technical operation of the software to include the audio instructions. At this point the production prototype was delivered to the BBC so completing the commercial production schedule. The second and third methodology pilots and technical changes indicated in chapter 2 *(see p. 36, p.38, p.39, p.41)* were actually carried out while the researcher was 'producer in residence' at the Centre for Electronic Arts at Middlesex University, from January 1996 to March 1997.

4.3 The second methodology pilot

The pilot was undertaken at the same JMI school. This section describes the detailed testing of the research methodology, the results that were recorded, and the changes made in preparation for the main study.

The qualitative research methodology chosen was within the context of descriptive research – where events have been arranged to happen – rather than experimental research in which events that have already occurred were accounted for (Cohen and Manion, 1980, p. 67). Rigour was provided by the collection of qualitative data from 3 sources – the Triangulation Method (Robson, 1993, p. 383). According to Cohen and Manion (1980, p. 233) triangulation gives the opportunity to 'map out or explain more fully the richness and complexity of human behaviour by studying it from more than one standpoint and, in so doing, by making more use of both qualitative and quantitative data'. The multi-method approach of observation and questionnaires using 3 different sources of data enabled the cross-referencing of records. Importantly it could reduce the potential for error and researcher bias and ensure validity.

The structure of the methodology is described here in a *Conceptual Framework* of the study – the Why, When, How, Who, What, Where description of the study – which is then presented in an *Overview*. This is then followed by a precise description of the *Procedures* – the data collection method. The *Observation* strategies employed are a study through time using the Time Series Analysis method (Robson, 1993, p. 382) with Key Events collected in a session summary. In the *Report*, the reporting method takes the form of a log using the narrative method. Finally, the *Evaluation* of qualitative data uses the quasi-judicial method, i.e. the research questions: What is at issue? What other relevant evidence might there be? How else might one make sense of the data? How was the data obtained? The results of the second test are now described.

The Overview

The headteacher of the JMI school was approached for written permission to carry out the second methodology recognising the need for a formal arrangement for an authoritative research exercise. A class teacher would now be involved as one source of the triangulation method. The researcher recognised the extra work required by teachers during their busy classroom schedule in the research design. The researcher was also aware of the importance of assessing the impact of working with a new teacher to the school who was required to acquire IT skills with minimum opportunity for training (Fisher, 1996). A music specialist was chosen. Impartiality was also an issue with regard to the researcher's involvement in the systems development; he has an interest in discovering that the system worked. The researcher was a parent governor and chair of the Curriculum Committee. Many children at the school also knew the researcher, due to frequent visits to the school and the proximity of his home to the school. Some children at the school helped in the recording of the sound instructions for the Research Tool CD-ROM. The researcher had already visited the school during the first methodology pilot. Impartiality was managed by the triangulation of sources.

The issues raised by the overview were dealt with, first, by preparing a letter to the school stating clearly that the software was under observation, not a teacher's use of the software, so clarifying the teacher's role. Second, by ensuring that the researcher's manner and approach were quietly formal. Third, by keeping to a minimum the preparation time by asking the teacher to briefly look at associated material prior to the research visit to the school. Fourth, by making it clear that the teacher should only watch over the researcher's observation session while carrying out their ordinary class supervision. Finally, the teacher would only be interviewed after the class had finished at the end of the morning or afternoon period.

Care was also taken to formalise the physical setting for the research. The computer was set up in the library next to the classroom. 3 children (all seven-year-olds) took part. There were other children using the library for study. The researcher sat to one side and slightly behind the children arranged round the computer.

Procedures

The second methodology pilot took place on a Friday morning from 9.30am to 1pm. The events took place in the following order:

1. The observation session began at 9.30 lasting for 40 minutes.
2. The children's interviews lasted for 1 hour 15 minutes with a break for lunch.
3. The teacher's interview lasted for 1 hour (lunch from 12-1pm).

The Data Collection Method

The 3 sources of information for the triangulation process were provided in the following way. A group of children were first asked to explore the software watched by the researcher in the observer role using the Descriptive Record Method. Then, each child in each group was interviewed about the use of the software. Finally, the researcher interviewed the teacher. The original plan was to interview the teacher during morning break. However, the teacher had to cover for an absent member of staff so it was agreed that she would come in and make frequent informal visits to observe, without involvement, children using the software during the morning and she would be free to talk at lunchtime.

Record sheets were designed for each of the 3 sources of information and detailed the following content:

1. Observation Schedule

   The observation form simply provided spaces for 3 areas of observation:

   What were children doing?

   Why were they doing it?

   What were children learning?

   These questions were considered to be essential questions at this stage. There were eight of these observations sheets, one for each of the interactive pages.

2. Pupils' Interview Schedule

   The second type of sheet was an interview schedule, which provided a list of key questions prompts and summary questions.

3. Teacher's Interview Schedule

   A similar questions list was used to guide a 'conversation' with the teacher.

4.4 Refining the final methodology design

This section describes the changes made to the final methodology as a result of the second methodology pilot. The main changes were documented in this section beginning with introducing the research to children, then changes to the observations, the design of the questionnaires and a refining of interviews, conversations with children and interviews with the teacher. The aim of the changes was to create a more focussed approach and to organise more accurate cross-referencing of the qualitative data to further reduce the potential for error and ensure validity. The final form of the interview schedules for the 3 sources of data are given in detail (*see Appendix 1*). The final methodology was to include the *Report* forming a log of results (see *chapter 5*) with an *Evaluation* of the data.

4.4.1 Introducing the research to children

It was observed that following the initial introduction, children spent time off-task asking questions about what the researcher was doing, what was expected of them and only then appeared to feel more confident to try using the mouse and make mistakes. It was therefore proposed that in the final version of the methodology for the main study, key statements should be made by the researcher during his introduction to the whole class that, as far as possible, addressed these concerns. It was also recognised to be essential to place the researcher as a passive observer in the mind of the class. However, interventions that were called for by children were to be allowed and to be recorded.

The Introduction Script

'Now I have brought along a computer program that I'd like you all to try. It is not a test for each of you. It is not a test and you don't have to do well or get the right answer. The reason I am here is to find out how you use the new software program on the computer. I want you to try the computer program out. Just try it out. Say what you like and what you don't like about it and what I'd like you to do is to give it a go and explore it and find out and see what you can do. I'm not going to say anything else other than it is about music; it is learning about music. My job is just to watch you. You can use the software on your own without me and I have asked—[the teacher] to have a watch what you are doing so I can ask [her] afterwards what [she] thinks about the software program, not about you.'

4.4.2 Refinement of the classroom observations

The Descriptive Record Method (DRM) employed to gain data from observations of children using the software was simplified. The aim of trying to identify each category: what pupils are doing, what they are learning and why are they doing it, was too complicated to achieve during the observations. The problem was solved by leaving space in the form for note taking and transferring the task of analysis until later, aided by the audio tape.

The reason for delaying analysis until after the event was that during the pilot, there were a wide range of different events taking place while children were working on the computer to attempt any categorisation during the observation period. However, grouping of observation categories during the process of collecting data during the pilot suggested to the researcher 3 areas for detailed study:

1. The quality of the instructions.
2. The quality of the screen design.
3. The user's experience of using the mouse to manipulate objects.

As a result the focus of the study was defined as the quality of interface interaction. Therefore the 'What is being learnt?' category was removed from the observation sheet.

In an attempt to overcome the observation issues that had been identified, consideration was given to techniques of recording events related to the quality of interface interaction in detail using a systematic recording method for recording a range of events as used, for example by McDevitt (1994). However, the systematic recording method with event recording systems was rejected as inappropriate to the study because it required too much 'head-down' attention to the sheet tick boxes. Instead, the observer should be 'head-up' watching children in a range of new forms of interaction created by the ability to manipulate elements on the screen using a mouse. Therefore, a more open-ended observation method was chosen to allow the observer to be receptive to as yet undefined interactive processes and patterns that might be taking place. For all these reasons the descriptive research method was finally chosen because it allowed the observer to be open to, and cope with, the range of undefined new interactions between children and computers. Instead of tick boxes identifying a range of predefined activities, spaces were provided for events taking place when children used each interface, including the opening screen, the six activities, the song, and the story.

The Descriptive Research Method gave the researcher flexibility to consider the context, the sequences, the meanings of naturally occurring events such as the starting points and finishing points of recording sequences – after the event. This was carried out by counting of events, noting patterns, themes, clustering, dividing up events into their smaller components, subsuming particulars and creating abstract categories of generalisation, making conceptual or theoretical coherence and general observations. Guidance for these techniques was provided by Simpson and Tusin (1995) and Munn and Drever (1995). The Descriptive Record Method was also the closest formal methodology to a report approach used by the researcher during his professional classroom experience evaluating radio programmes referred to in chapter 1. The researcher was well-practised in lengthy concentration, focussed and detailed observation of events with children.

During the second pilot children were observed to run through the software once and return to work through it again. The reason for their behaviour appeared to be that the first run through comprised activities of children finding their way about. It was at this point that the significance of a key feature of children's general learning that children need to test out and talk while engaged in manipulative tasks was also observed, in this case solving mouse manipulation problems. The second run through was a more thorough listening to instructions focussing on the activities. The final improved observation sheet allowed for the recording of these events.

All the changes to the observation schedule focussed the researcher's role as an efficient, impartial and detached observer, not distracted by complex counting of events as they happened, and therefore enhanced the researcher's ability to concentrate on events as they occurred. The quality of the observation method was also significantly improved, not only by the revised observation form, but also by the new digital audio technology and database software described in more detail below.

4.4.3 Question schedule for individual interviews with children

The schedule of questions for children was refined in the light of previous experience gained. First, questions were organised in similar sequence and focus to the observations schedule, opening screen, activities, story and song. The questions in each sequence were then organised to obtain data on the 3 themes of: the quality of the instructions, the quality of the screen design, and the user's experience of using a mouse to manipulate objects. The interview was organised so that questioning was not confused or compromised by interventions achieved by giving prompts and supplementary questions a formalised place and a clear role in the questionnaire. The appropriate language for the age group was tested requiring a rephrasing of questions. The finalised list of questions, their grouping and focus of interest was mirrored in an adult form for the teacher interview schedule for effective cross-referencing.

Children's answers could be recorded clearly on the minidisc. Interviews where given in front of the computer allowing the pupil to refer to or even demonstrate issues. Also as children used the computer, the audio instructions and sound effects punctuated the audio recording as useful reference points for the researcher. Video recordings would have been complex and time consuming to carry out and analyse by comparison.

4.4.4 Interview schedule with the teacher

The role of the teacher in the study was reviewed. The original plan had been for the teacher to listen to the radio programme to gain familiarity with the material. The teacher was now only asked to observe pupils using the software during the day without intervention. This was intended to replicate the minimum involvement of the teacher dealing with computers in a busy classroom. The change focussed the study on the interaction of children around the computer, not a teacher's role. The question schedule structure and content was based on similar questions asked to children. There was an additional section searching for data on the use of the teachers' control panel (see Appendix 1).

4.4.5 Final adjustments to the research methodology for the main study

There were a number of further adjustments made to the data collection schedules for the main study. They are listed here:

1. A section initially designed for teachers was extended to the children's schedule using appropriate language so more information could be cross-referenced.
2. The interview schedules were further piloted with the assistance of a trainee teacher to ascertain the clarity of the questions.
3. The phrasing of the questions was refined to avoid potential for ambiguity.
4. The teacher's interview schedule was sent to the teacher beforehand so that teachers had time to assimilate their role and information required prior to the day of the visit.
5. The children's interview schedule was reordered to make a more logical sequence, i.e. asking children to describe what was happening before asking qualitative questions about feelings and preferences, and amended complicated phrasing by using simpler constructions. Only a few changes had to be made as questions had already been substantially tested.
6. Questions about the opening screen were added – the result of an oversight in the original scheme.

7. The researcher undertook a final check of the language in the cross-referencing of questions. Questions in the open ended format were rephrased and key words given prominence in the sentence structure to ensure accuracy and clarity and to ensure their accuracy.

4. 5 Technical issues remaining

There were no changes made to the software after the second pilot. The possibility of further software changes was identified, but these could not have been made because of programming costs and time issues. These were: to stop the moons disappearing momentarily in Activity 6, to make the listeners appear to zoom into the story as it starts (past Granny and through her window), and to allow children to leave the story at any time. Activity 6 might have been better broken up into separate sections to make it more focussed. Activity 3 could have been provided with a repeat button so children could reset the activity. The star words could have been revealed as letters as well as audio in Activity 3 to help recognition of terms. The effect of revealing the beater as Activity 4 began, so children had a clearer idea of what could be accomplished was too technically complicated to achieve, and the limitation was recognised.

The next section is a description of the new digital techniques used to enhance the quality of the research data and the methodology, by improving technical aspects and dependability of data collection and data analysis.

4.6 Use of the digital audio recorder

The new Sony Minidisc digital audio recorder had just been released during the period of the methodology study. The researcher's experience in radio production led to an interest in exploring the potential of digital audio in assessing the Research Tool. The audio solution solved the issue discovered in the first methodology pilot, which revealed that the quantity of information was too great to record on paper by hand as it happened. The use of a video recorder was rejected because of the complexity and expense of recording the screen and children at the same time and because of the sound quality.

The digital audio recording experiments in the first pilot were first intended to act as an aide-mémoire to the observations using the ability of the digital technology to record date, start and finish times on the minidisc. The original plan was for the recordings not to be transcribed in their entirety but just used to check detail and times and to guide a full writing up of the research session afterwards.

It was noted that Tizard and Hughes (1985) found taped conversations as a record for analysis of interactions inadequate without notes. The researcher demonstrates that digital technology can assist in improving this process. The second methodology pilot firmly established that the new digital audio recorder allowed questions and answers in the child and teacher interview schedules to be recorded clearly and effectively. Also, recordings to support the observation schedule could be made effectively by using stereo imaging to identify individual children speaking in a group of 3, with the aid of a simple diagram added to the observation schedule. This was possible because the digital recorder worked close to the computer without the interference to which analogue machines are prone. The excellent quality of the digital recordings also recorded the mouse clicks and, more importantly, the audio instructions from the software. The effectiveness of the combined results gave the researcher a clear recall reference to analyse the interactions track where children were in the software, and establish what children were doing while they were making comments, quickly and easily. The research could concentrate on observing the issues arising without being distracted by making detailed notes about every aspect of interactions.

The researcher also discovered that the digital recorder allowed much faster and efficient replay of the recordings. This was because the digital technology makes it possible for the researcher to not just digitally mark relevant passages, and to do this without stopping the playback, but also the digital 'rewind' worked almost instantly, far quicker and easier than previously possible with the tape recorders of Tizard and Hughes's experience. The digital recorder is small in size so children were not distracted by its use. Finally, the 6 hours of continual uninterrupted recording time without fear of minidisc or battery running out, also allowed the researcher to focus on the observations without distraction.

4. 7 Use of a computer database

The researcher tested out the use of a computer database in combination with the digital recorder, rather than using a conventional file card reference method to analyse the findings. The new digital audio recorder proved to be every bit as effective in conjunction with the database. The quality of sound and the speed and accuracy of the digital rewind function facilitated easy transcriptions of answers to questions directly into the computer. Therefore it was a realistic option to transcribe answers to all questions in detail straight into the FileMaker Pro database software. Examples of the electronic file card are indicated below *(Figures 4.1, 4.2 and 4.3).*

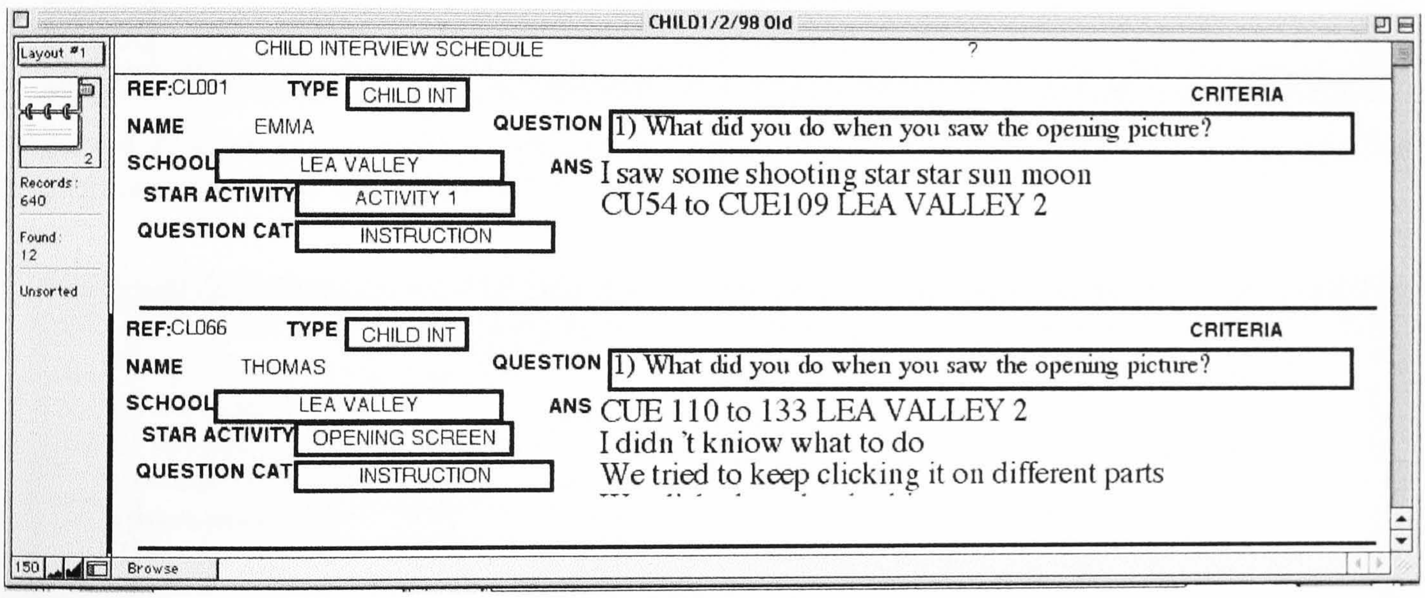


Figure 4.1: Example: Children's Interview Schedule FileMaker Database. (Howarth, 1997)

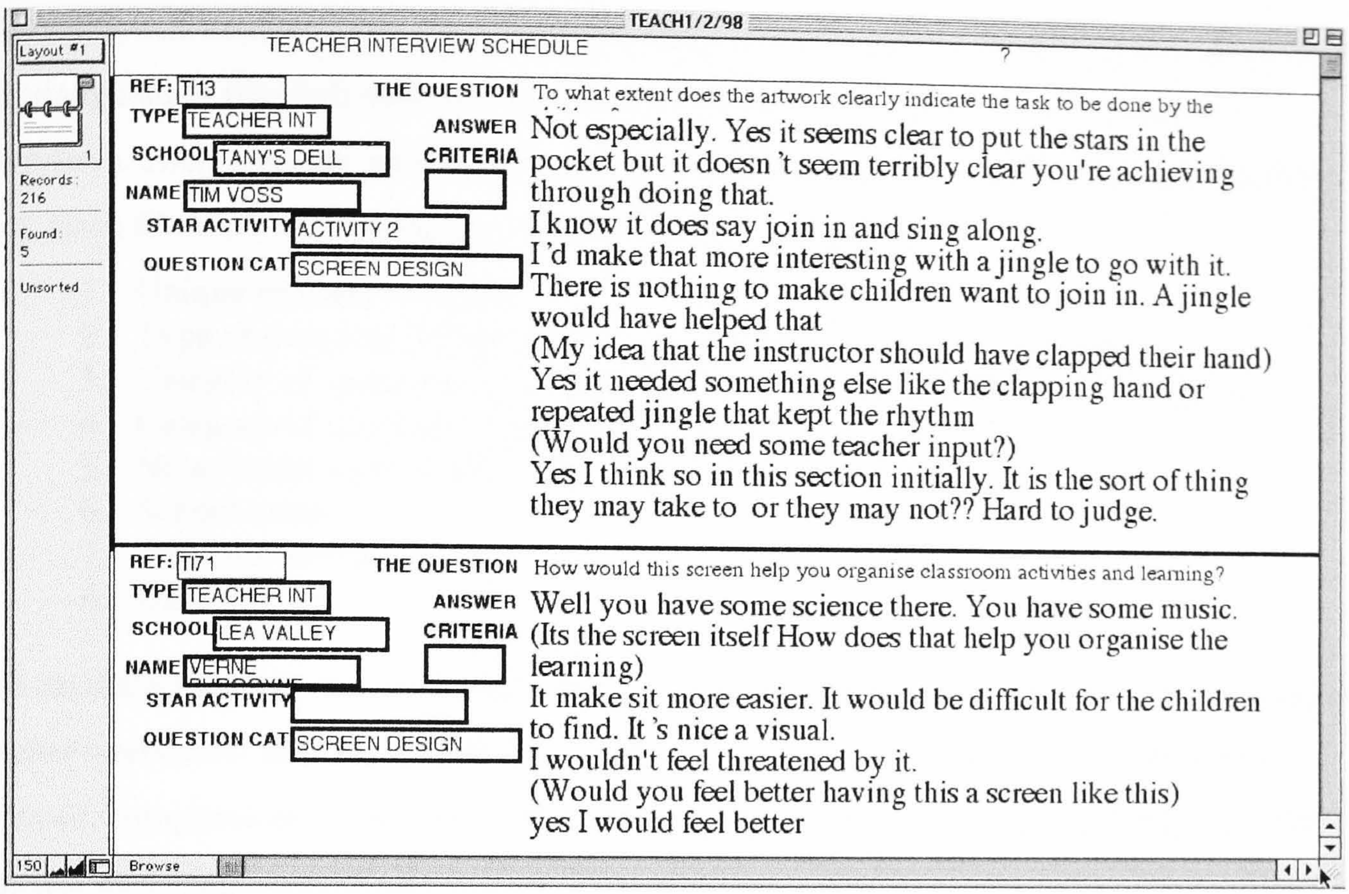


Figure 4.2: Example: Teacher's Interview Schedule FileMaker Database, showing expanding pop-up text boxes for automatically accommodating lengthy answers. (Howarth, 1997)

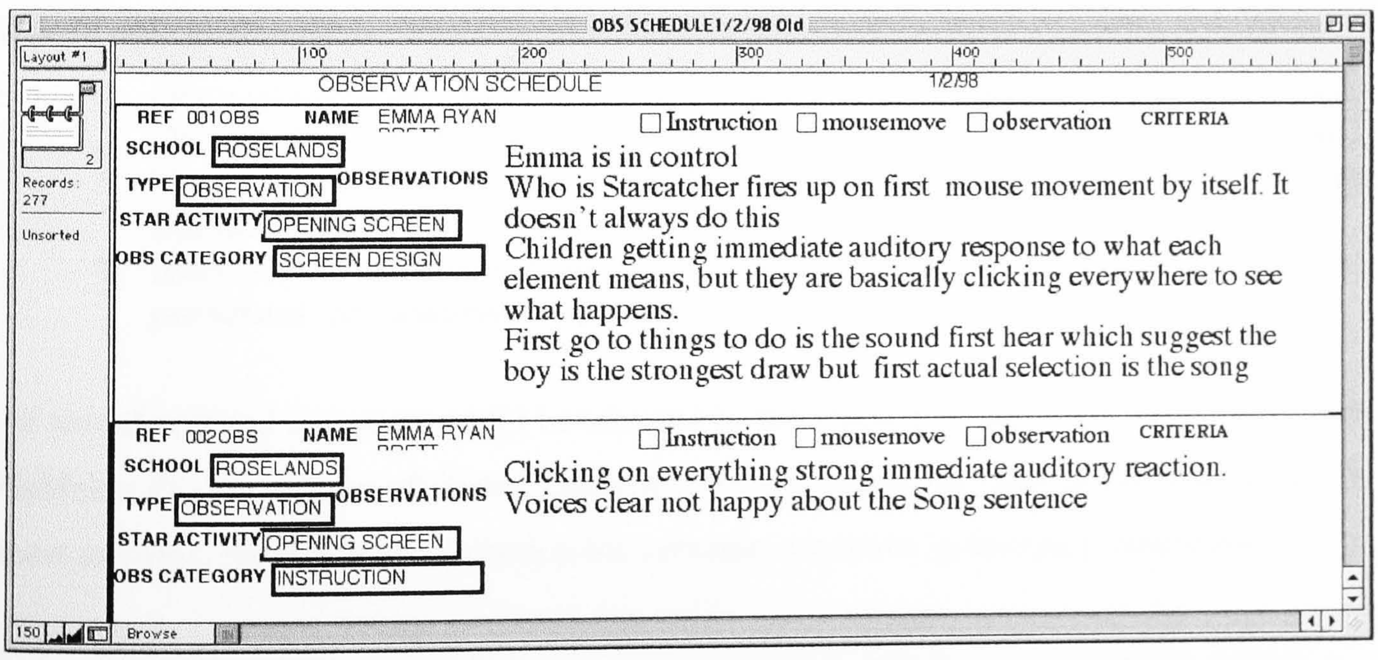


Figure 4.3: Example: Observation Schedule FileMaker Database. (Howarth, 1997)

FileMaker was used to create the 3 separate databases, each one a source of the 3 elements of the triangulation research method: observations, children's interviews, and teacher's interviews. Each question with its completely transcribed answer formed one separate file card. Each file card also contained separate searchable fields for:

1. Unique reference number
2. Type of schedule (observation, teacher interview, child interview)
3. Category of questions (screen design, instructions and mouse movements)
4. Category of interface (eight activity titles)
5. Notes under each of the 3 categories in the observation schedule
6. School name
7. Interviewee's name
8. Date

The database was tested as to whether relevant questions and categories from the observations, teacher interviews, and child interviews could be manually combined, cross-referenced, grouped, compared and analysed using printed out data from the second methodology pilot. The test exceeded expectations in terms of speed and accuracy of data collation and ability to make comparisons of data. For example, the electronic search facility in the software was used to print out collations for manual comparison, counting and interpretation in the following kinds of data print-outs:

1. One question asked about one interface from one schedule from one school only.
2. One question asked about one interface from one schedule from several schools.
3. One question asked about one interface gathered from the two interview schedules, and matched observations (all data sources).
4. Individual word search of positive and negative words relating to each interface, per school, per schedule, and across all schedules.

The text of collated responses could be selected by the researcher and easily transferred from FileMaker Pro into Microsoft Word. Once in a Word text file, the copy could be available for closer analysis, reflection and selection for verbatim quotation in the thesis document.

A newer version of the software was released during this period and allowed for individual words to be searched within each field. For example, it was possible to collate in one new print-out file, all responses using the same positive or negative word in answers about one interface, from all children, a teacher's response and the researcher's observations of the same interface.

The comparing and contrasting, grouping and counting events using the print-outs made the process of analysing the responses more accurate and efficient with a smaller potential for human error, and were achieved more quickly and with less fatigue than in conventional methods. For example, there was no need to search manually through pages of transcriptions to find the required data or manage a card index system. Exact transcriptions could be compared next to each other on the print-outs. The process affirmed the validation requirements for the triangulation method, so the FileMaker database software was chosen for the same techniques of compilation and analysis of data for the main study.

4.8 Summary of changes for the final methodology design

The iterative refinements made to the methodology of the qualitative research through 3 pilot stages are summarised as follows:

1. Selecting the Descriptive Record Method in preference to the Systematic Recording Method.

2. Refocussing the areas of research to four main components for study:
   i. The design and screen layout.
   ii. The instructions.
   iii. Actions involving the movement of objects with the mouse.
   iv. A teachers' control panel.

3. Refining the methods for recording and interpreting data accurately:
   i. Reorganising and rephrasing questions.
   ii. Redesigning questionnaires.
   iii. Introducing digital audio technology and a computer database system.

4. Ensuring validity of the triangulation process
   i. Confirming the methods chosen.
   ii. Confirming the coherence of methods chosen.
   iii. Showing how the data is to be used.

4.9 Defining the research question

The process of the development of the Research Tool, the literature review and the refining of the methodology, led to a first draft of the research question, reflecting the emerging importance of exploring a range of methods of greater depth of engagement including the physical manipulation of objects using the mouse:

> **What are the elements of movement in the Research Tool interface design that improve the quality of engagement?**

The final version became:

> **What are the design features required to improve the quality of computer interface interaction for 5 to 7-year-old children?**

A more general brief which substituted 'design features' for 'elements of movement' and 'interaction' for 'engagement' was a device to allow a more precise study of the nature of the engagement using the data from the 3 components of interaction: instructions, screen design, and mouse manipulation and the value of a teachers' control panel. In particular, the decision to replace 'engagement' by 'interaction' was based on a view that engagement had a range of undefined features with a qualitative value. Interaction, on the other hand is a descriptive noun in common usage in the field of study and its meaning could be illuminated precisely. The change allowed a more precise understanding of interaction by subjecting the evidence arising from the four main components to the ten criteria.

4.10 The criteria informing the main research question

The criteria, on which to base the evaluation of the four components, comprising the quality of interaction were refined by the methodology piloting. The criteria are indicated below in Table 4.1:

Section A: Standard Interface Design Practice 1. Are users clear about what task they can do with the interface? 2. Are users clear how to make the interface work? 3. Are users clear about what is happening when they use the interface? 4. Do users find it easy to navigate around the software product?
Section B: Innovative Design Features of the Pilot Software 5. Is the interface activity an enjoyable and absorbing educational experience? 6. Does the interface activity engage the user in concentrated activity through movement? 7. Is the control of movement of an object easy for small hands to achieve? 8. Do small changes in the design of screen activities stimulate involvement of the user? 9. Does the interface have multi-functionality within an activity creating flexibility that enhances the quality of engagement, but does not cause confusion? 10. Is the totality of interface activities in a product capable of flexible organisation by the teacher to facilitate learning?

Table 4.1: Criteria informing the main research question.

4.11 Summary

The piloting process resulted in a main study with a tried and tested methodology. The methodology produced data to inform a set of clearly defined criteria to answer the refined main research question.

Chapter 5: The main study

5.1 Introduction

The first part of the chapter explains the organisation and procedures of the main study. The second part draws together the data obtained. The final part of the chapter is a summary of the research data to address the ten criteria used in chapter 6 to answer the main research question:

What are the design features required to improve the quality of computer interface interaction for 5 to 7-year-old children?

5. 2 The organisation of the main study

The following Hertfordshire schools were chosen for the study. The visits were made by the researcher between 9th and 20th May 1997.

1. School A, in Harlow is described by the headteacher 'as a primary school of 200 children with limited IT support.' The teacher interviewed described the school as consisting of mainly pupils with a working-class background, many families with strong emotional problems, but still a happy, friendly school; the aim being to create an atmosphere some do not have at home. Most children in the class were aged 9 but their ability was generally below the country average.
2. School B, in Harpenden is average in its resources and variety of catchment area.
3. School C, also in Harpenden is a formal school in a prosperous area with limited IT resources.
4. School D, in Hoddesdon is the county's model IT school with a first class, well-informed headteacher and generous IT facilities.

The schools were chosen to give a sample of pupils with a wide range of abilities. The aim was to achieve a variety in quality in both pupil and teacher abilities as the priority was not to test the teachers' abilities or the IT provision, but the Research Tool, whatever the classroom situation. The schools were chosen from locations away from the researcher's home area and were unknown to the researcher, except for School B where the researcher had made visits a year previously while at the BBC.

Each visit lasted a whole school day and was organised to follow the same sequence. The day began, whilst children were at assembly, setting up the Macintosh computer on which the

Research Tool was installed and the Minidisc digital audio recorder in the classroom. Then the researcher met the whole class and explained the project using the pre-defined introduction presentation. Before lunch every member of the class, in groups of 3, worked their way through the activities watched by the researcher following the Observation Schedule. In some cases children stayed on during the lunch hour because of the large number of children in the class. After lunch, the researcher carried out the individual Child Interview Schedule. It had been hoped to interview the teacher at lunchtime, but in all cases it was more convenient for the teacher to stay behind after pupils had left. In all, the schools provided the following sample numbers for the study:

Total number of pupils observed: 110
Total number of pupils individually interviewed: 17
Total number of teachers interviewed: 6

5. 3 The organisation of data

First, evidence from the researcher's observations, the audio recordings of interviews with children and interviews with teachers were gathered in response to the 8 different interfaces in the Research Tool. The information was transcribed into Microsoft Word and then placed in the 3 corresponding database files in the Filemaker Pro software as described in the research methodology in chapter 4. The work was carried out by first listening to the digital minidiscs, and digitally marking the beginnings of each question for quick reference and making notes of key comments for the second listening, when transcription took place. Observation notes for each interface were entered by the researcher and each field in the databases manually checked for correct operation and accurate numbering.

The data were then analysed manually using the electronic file cards, which were searched, and responses to the questions collated using the software's 'find' function and then by printing out the collated data. The 'find' and 'layout' options of the software were flexible so that on-screen the whole card could be viewed. Also, individual responses could be presented in such a way that, for example, many responses to one question could be collated for analysis in a condensed format on a few pages for efficient comparison. Using this technique the replies to one question could be accurately cross-referenced across the 3 sources of data as described in the second pilot. The research data material was constructed around the ten activities of the Research Tool presented to the groups of three children (110 in total) and the individually interviewed children (17), and the teachers (6) and are listed here as a reminder of the interfaces described in chapter 2. These are as follows:

The Opening Screen:	Users choose from icons representing 'stories', 'songs', 'things to do' (activities)
Activity 1:	Users click and drag letters to spell, 'star', 'moon', 'sun' from 3 jumbled sets of letters.
Activity 2:	Users put into a boy's pockets 'star' and 'shooting star' icons to aid familiarisation with music pattern.
Activity 3:	Users put planet icons into a series of pockets, to make a rhythmic pattern. Users learn about the structure of musical notes, using the syllable pattern of words as examples.
Activity 4:	Users create star tunes using percussion instruments – choosing an instrument for each star, moon and sun picture.
Activity 5:	Users choose a music sound for different stars – 5 stars each with different instrument sounds. When the instrument for each star is chosen a tune plays.
Activity 6:	Users hear and see demonstrated the main phrase of the Holst's 'Jupiter' (To Thee My Country) theme with the aim of identifying a tune. They can recreate the tune and then create their own tune using the same notes.
Story:	Icons of children are 'click and dragged' by users into Granny's house and she tells the first episode of 12 stories of Starcatcher.
Song:	Users hear all or part of the first verse of one of the many songs from the radio series by clicking on moon icons.
Teacher's Control Panel:	The 7 stars on the opening screen that switch on or off items from each list of 7 lists: Programme Options, Story Options, Song Options, Activity Options, Sound Controls, Teachers' Notes, Star Words.

5.4 The evidence

The evidence from the main study is presented in this section of the chapter by collating the responses to each of 4 features of interface design to improve the quality of interface interaction which are:

1. The audio and written instructions.
2. The screen design.
3. The mouse movements – the operation of the interactive features.
4. The teachers' control panel.

In the second part of this section each of these 4 features was assessed in terms of the ten criteria listed in Section A: Standard Interface Design Practice and Section B: Innovative Design Features of Research Tool, as described at the end of chapter 4.

Within each section of the chapter dealing with the audio and written instructions, screen design, and mouse movements, evidence was generally presented in the order in which children used the interfaces. The evidence was the result of the researcher counting events and counting positive and negative responses to questions and carrying out word searches across each of the databases. The typical number of cross-referenced responses was 15 for each question drawn from the responses in individual interviews, 6 teacher interviews and 110 observations in groups of three children. Numbers were added for clarity not statistical significance. In other cases, the general terms 'most' or 'some' were used. At the end of the chapter responses were quantified, analysed and discussed. The reader should refer to the Research Tool on the computer while reading the text below.

The opening screen was the obvious starting point as it was the first contact a user has with the Research Tool. It has the potential to set the tone and create expectation of the subsequent use. It also presented a child with a new situation to be dealt with, a challenge and an opportunity for co-operation or conflict with the peer group.

5.4.1 The role of written and audio instructions

The first of 3 key questions about the instructional element of each interface was *'Did you understand what children were telling you to do?'* The aim of this question was to explore and elicit an understanding of the role of the text and sound instructions that used children's images and voices within the interfaces.

The Opening Interface This screen elicited a wide range of responses from children. Most child interviewees expressed a preference for clicking on the star, slightly fewer wanted to click everywhere to 'see what happened'. Considerably fewer preferred the boy followed by the grandmother and then the girl as clickable items.

Observation evidence differed. Most interviewees appeared to want to click on the boy, then the star, followed by clicking indiscriminately with Granny and the girl the least popular. This observation would tend to confirm that children consistently went to the 'things to do' section (the boy icon) first.

Teachers thought that the open question *'Who is Starcatcher?'* was lost in the other information and that the spoken phrase should have been included as a roll-over, possibly on the star. However, one teacher thought that despite the question being provided: 'They would still explore. I don't think they stop and listen, because the mouse is there. The nature of having a mouse is to click and find out, not listen and find out.'

Teachers commented on the boy as the most popular object quoting his position pointing at the star, being a boy and the reference to 'Things to do' as the most exciting aspects. Gender issues were not investigated in this research. The focus was the transfer of existing resources to multimedia. In the original illustration the image of the boy was pointing to the Star and the impression of action was used in the multimedia version for the sequence of activities.

The opening interface presented children with an open question. 'Who is Starcatcher?' in text and audio. The effect of using an open question appeared to work. The opening page was observed not only to be exciting to children, but also provided a confusion of images. The confusion was compounded by the roll-overs, which operated quickly with audio and visual feedback and instantly took users to the new 'page'.

Activity 1, in contrast to the exciting confusion of the opening screen was visually and intellectually much less demanding, with one main task: to click and drag a letter from a jumbled list into a box to spell a word correctly.

Children's comments, observations and teachers' interviews confirmed the clarity of the instruction and the task. One teacher thought the written instruction should appear on the screen as well and that a demonstration might help too. However, the physical task required manual dexterity skills, which were the focus of attention, and the subject of group discussion and involvement.

Activity 2, in contrast, required children to do 3 physical tasks. First, the audio instruction was to put 4 icons into each of 4 pockets of a boy and sing along and clap hands in time with the rhythm of the name of each icon repeated four times after the last icon of the 3 sets of 'star', 'shooting star', 'shining brightly' icons was placed correctly in the pocket. The audio file was provided four times emphasising the beats in the rhythm i.e. 'shi-ning bright-ly'.

Most children were observed not to clap their hands, and noticeably longer was taken to work out what to do in comparison with the previous task. More time was spent discussing, asking questions and telling each other what to do. The children's response was that most understood the early instructions. Yet no one mentioned clapping hands at all, with only 2 references out of 14 even mentioning putting icons into the pockets and 'it would say the words'. There was a concern in the interviews with teachers about the number of instructions that children can absorb.

Activity 3 required children to absorb 4 elements in the instructions: put icons into pockets, replace them with other icons, move the pockets around, and clap hands to the chanted rhythm of the words as the sequence played when the last icon was put in the pocket. They were also asked to, 'Put more star words in more pockets and see what happens.'

The main feature of the observations and interviews of this activity was that the discussion had a reflective element as children talked about what the icons were, before they put them in the pockets. Another key feature was that the hand-clapping task was only carried out by a small minority.

Activity 4 had 3 elements to it but children did need to memorise a large amount of the instructions as in the previous activities. The reason is possibly partly because of inherent problems with the design. This only allowed users to click on a beater to play the instrument that appeared once the instrument icon had been moved to the star, moon, and sun symbols. The instrument disappeared and the beater appeared. Only then could it be moved around to the 3 symbols to create a tune at random.

From observation children quickly moved the instruments to the symbols. Most children were able to remember what to do for the last activity in the instructions, which was to engage in discussion about trying each instrumental sound to capture the feeling of each of the symbols. Two children began to discuss the relative merits.

Activity 4 had an attractiveness that set it apart from the previous elements. All individually questioned children except one, said they understood the task to be carried out. A teacher thought the instructions were fine, 'because you're focussed in on what you have to do and then what you have to do with it. Also it's telling you something you can make.' However, one teacher pointed to the conflict between instruction and actual events on the screen, 'It asks them to use the beater and they'll look on that screen and say, "It hasn't got a beater." You don't get the beater until you've done it, but they [children] learn by doing.'

Activity 5 instructions were observed to be clearly understood, but the operation of the reward or results of the actions differed from previous screens: the instruments were put into the star symbols. The instrument symbols disappeared. The symbols were all variations of one star design. However, in this activity, the sounds started to play automatically with no way of stopping them until they finished. If they were moved around as instructed, the tune continued to play.

From all the observations it was clear that children's ability to memorise what the sounds were and in what order they should be moved was very limited because the instrument icons disappeared as they were put into the symbols. Some children started to make their choice of sound as in the previous activity, but control was taken away from them as the sequence started playing automatically. 'It just does it itself' summed up the attitude. Children were generally confused, lost interest and moved on. Some children were also frustrated, others were trying to make it work clicking and struggling to move things around (which was not possible once the sequence started playing). The activity was observed to be the most confusing of all interfaces in the Research Tool.

Teachers identified one key element, 'Oh I see it moves on top of it. Why does it work sometimes with you [the user] clicking it and why sometimes without?' And, 'I was expecting it to be exactly the same as before [the previous activity]. Was I to move the star around or was it these [the instrument icons], because I'm sure I heard "move the star around?" '

Activity 6 was the most popular of all the activities. The instructions for Activity 6 were staged, with a demonstration of what to do and a pause for children to act, with the opportunity to do a further open-ended activity. The task was to listen to the demonstration of 12 bars of the 'Jupiter' planet suite by Holst, then a sung (la-la) version by the teacher, to click on a large icon of the planet Jupiter to hear the orchestral version as a series of icons (Jupiter's planets) highlighted. Children were then invited to play the tune. The tune was a la-la version. (It was technically too complicated to 'cut up' the orchestral version.) Children were observed to be listening more closely to the instructions for this activity.

Noticeably, unlike other instructions, one child recalled exactly what the task was, 'What you have to do is, you had to listen to this about the music, then put the music on and then remember and then do the tune with the moons.'

The pattern here seems to suggest a case for the value of a '*sequenced construction of audio instructions*' because the pattern of the sequence follows the most traditional of educational credo in a new media form: i.e. 'Tell them what is about to happen, demonstrate it, repeat it, do it yourself, repeat it again, and then add a small change that further advances learning.'

On the other hand one child said, 'I thought you could move them around and make a different tune', based on the expectations created by the previous interface. (It was possible to play another tune but not move the moons around.)

All teachers thought this interface was very attractive 'The planets, the interaction between sound and visual, and movement by hand, and the sound is the strength.' 'This is more didactic isn't it. Nice and clear.' 'The music echoes the voice.' 'They can go back...[and have another go]. There is flexibility.' 'There is lots to do.' 'I've heard a child say they feel sad at the music.' 'These [icons] are very close.' 'The visual clues I noticed.' 'He played those 3 notes as the same because he went by colour.' This teacher thought there was the opportunity for another level of instruction 'There could be another level where they can play their own tune. Can you move them round?' (Researcher: 'No.') There was comment about the delay caused by the software making it difficult for children to click and get a note quickly.

In response to a supplementary question 'Why do you think they are spending so much time on this?' one teacher responded, 'Because they can create their own music. They feel very special. Specially those children who don't play an instrument.'

In response to a discussion about extension activities in the classroom, these instructions were stated to have the quality of offering a child further opportunity for action and, as one teacher put it, 'Yes, so they have a chance to think, "Well what is this?" and "What is that?" "I can go on to do this." They can work out what they're going to do.'

The Story Activity has 3 components, the first being a screen showing 4 icons of children outside grandmother's house at night – children had to click and drag each of the child icons and take them into the house. The second screen showed children with grandmother in the sitting room. Finally, the Starcatcher story animation appeared as children asked Granny to tell them a story.

The general observation was that there were too many words of spoken instructions for children to absorb and that the aim of the activity was lost in the operation of moving the child icons into the house.

The Song Activity consisted of a single screen with one verse and chorus of the Starcatcher song. At the beginning of each line was a small moon icon. Clicking on the icon started and stopped the song, which, when the sound files started, highlighted each word.

The researcher's observations record that the instruction, 'Click on the moon and see what happens' was not precise enough and that, 'Join in and sing along' might elicit a more positive response.

5.4.2 The role of screen design

The second of the 3 key questions asked during the research was *'Was it clear what you had to do just from the pictures on the screen?'* This section collates the evidence of responses to the focus on screen design. The screen design was taken to include the visual artwork and the layout and does not include the interactivity element, which was the focus of the mouse movement section.

The Opening Interface The impact of audio instructions and the screen design operated together for the reasons indicated in the previous section.

Activity 1 observations showed most children were clear what they were required to do just from the picture itself. Children started the activity straight way after the sound instruction was heard. There was some expectation that it was necessary to type the letters in. However, in all cases there was discussion on how to do the task but the discussion was caused by the difficulty in mastering the click and drag routine.

Teachers commented that the artwork was not enough in itself to give clear guidelines what to do. Verbal instructions were required. One teacher thought the artwork was good enough to keep their interest. However, the artwork was not enough alone to indicate the task. 'But then very few (CD-ROM screens) do that.'

Activity 2 observations showed unanimous and immediate understanding of what had to be done. The pockets were recognised as pockets and, with a 'Wow' and a 'This is brilliant', children were observed getting right on with the task. A group of 7-year-olds waited for a period of 20 seconds to work out what to do.

Children who were interviewed were not quite so confident that they understood what to do, with 6 out of 11 responding positively.

The 4 teachers were divided equally in their responses. Two thought that though what was to be done appeared to be clear from the artwork alone, what was to be achieved was not clear, and suggested there was nothing to indicate just from the visuals that children should put things in the pockets or that they should also join in the clapping activity. The design was not especially clear. The other two thought the screen design was lovely, and that a bright child would work out immediately what needed to be done.

Activity 3 The main observation of Activity 3 was that from the visual design perspective children chose the most pleasing planet to put in the pockets, seeing them as favourite shapes or wanting to reveal what they were from the audio response, even before the instructions were finished. Identifying what the icons were from the visual image alone took up some time – suggesting that the icons were not drawn clearly enough. One group was organising the order of the icons in the pockets into stars and then planets.

Two out of 8 child interviewees thought the pictures did not give a clear idea of what to do. Teachers thought that the experience of the previous 'pocket' activity would make the screen design clear about what had to be done.

Activity 4 at first caused one group of children to be observed from the visual design perspective to have difficulty working out what to do. When the beater appeared after moving one of the instruments into one of the icons, they thought it was a spoon. The instrument icons disappeared as they were put into the symbol too. The loss of visual clues at this level also caused discussion as to what to do. There was no obvious visual relationship between the instruments and the icons as existed in the previous pockets activity. It was not possible to move the star icons around as in the previous activity.

Five out of 9 children thought they were clear what to do just from the pictures on the screen.

Two teachers thought the screen was clearly understandable, two said, 'Where's the beater?'

Activity 5 was observed to cause children difficulty in working out how to use it from the visual information alone and after a few seconds went on to the next activity. Those who persevered did not appear to be happy. The instrument icons disappeared when they were put into the star icons, and then they started playing before they could be moved around. There was no reward or reassurance of a clear visual feedback. One group tried to move the stars to the instrument icons, which suggest there was confusion as to the layout of images or their visual priority. There were just two lines of icons of visually equivalent in terms of colour and size, and dependent on the sound instruction alone for the clue what to do.

Seven out of 10 children understood what to do from the way they conducted themselves.

A teacher pointed out a problem caused by the disappearing icons, 'If they are at all like me they'll have forgotten what they're supposed to put there.' Another said, 'I feel like the village idiot here – I'm not quite sure how this works.' Another said, 'It doesn't show as much excitement. You don't have a beater. All they want to do in a music lesson is get to the beater. Sit anywhere near them and they'll be playing with that beater, straight away. Here they haven't and you don't know what's coming.'

Activity 6, in contrast to the previous example was observed to absorb children in a variety of ways. It was common for children to start singing with the narrator's voice right away in the demonstration element of the instruction. Children were co-operating, working together to solve the problem of making it work.

Children watched the moons highlight as the main 'Jupiter' tune played. These moons also highlighted when children played them. One child tried to click on the moons and drag them about. Another child tried to roll-over the moons instead of clicking on them. One child clicked on one moon and waited, possibly expecting the whole tune to play from one click. One boy explored all sorts of different combinations of the moons.

It was common for children not to listen to the whole instruction but to click on Jupiter right away. It is the biggest element on the screen. However, children were heard saying, 'How are we supposed to know which one is which?' (i.e. their names presumably) and 'Put it on Mars – it might be funky music.' Some children did not realise that the planets were illustrating the main tune – 'It is the brown planet that people eat.'

Out of 9 children, 3 answered clearly that they understood what to do from the illustrations, 6 said they did not know what to do.

The Story Activity With the Opening Story Screen, children were observed to talk more and with a wide variety of comments when solving the operation of this interface

There was little response to the Meeting Granny Screen partly because the dialogue to this screen started on a slight movement of the mouse. The audio was self-explanatory and Granny started to tell the story. This screen cleared to display the Story Screen.

The story page itself consisted of a screen of stars. As the story unfolded, some of the stars disappeared and the Starcatcher, made of stars, appeared as a small black figure which moved across the screen. The figure produced a small catch net, gathered some stars and then each of the stars forming the outline of the figure turned a golden yellow.

Four out of 7 children interviewed knew what to do on this page just from the screen design.

One teacher thought the opening story screen design gave them the impression 'Starcatcher is inside because they glow and because they're being drawn in. The whole house is glowing.' 'Is Granny Starcatcher?'

Another teacher thought, 'The light coming from that was good because it obviously indicates the focal point of the picture.'

A third teacher thought it did not matter that there is an instruction immediately the screen appears, 'They will click all over. Whilst it doesn't react I like it because it is exciting. While I watched children doing this they were absorbed instantly, because they have to focus on something. I think that is a good start.'

A fourth teacher thought the artwork indicated the task clearly, 'In that the door is open. There are lots of stories where the door is open, where you go through an open door where you follow through, but I think it is a good idea there aren't any words on it that they find out by clicking on the person. Although the very first person I clicked and didn't move.' Researcher: 'You want them to click to move them through the door?' Teacher: 'It's nothing that we planned but children think that's it. If they've clicked that they think they've done it.'

The Song Activity Most children joined in to the Song Activity right away. Children reacted quickly and most started singing. Everyone in these observations could read the words in the song. Children jigged about in their seats. Very few tried to learn the words. Those who were observed to be less interested in the subject matter clicked on and off the lines and tried to click on the words as they highlighted. Most children only played and joined in the song once before clicking, 'Back'.

5 out of 7 children understood what to do just from the pictures from the way they conducted themselves.

All the teachers agreed, 'Yes, though you have got a choice and some might go to the chorus first, because we have a duty to learn that first. We teach them [the chorus] first [normally in class]. Could you have had a larger moon or one dark until you clicked on it?' 'Without the voice? From their experience of other CDs, I would imagine yes [they would know what to do].'

5.4.3 The role of mouse movements

This section is confined to observations specifically about 'click and drag' mouse movements, i.e. in terms of how the mouse was used to move objects around.

The Opening Interface 'Click and drag' mouse movement was not applicable to the opening interface. However, in terms of where the mouse was moved, children were observed to be clicking on everything with preferences as discussed elsewhere (*see page 76*). It was possible to use the mouse movements to create several features, i.e. highlight the three figures, make three sets of words appear and three corresponding sound files play. When one or two of the groups were excited and 'roll-overed' frantically, the effect was to fire off a quick moving range of events and the result was confusion.

The ability of the mouse to not only provide feedback from a roll-over but also from three hot-spot areas sent some children off in one direction instantly. Most children discussed what to do. One or two groups, who had been identified by the teacher as having little computer experience, stared at the screen and did not touch the mouse, but tried to use the keyboard.

Activity 1 involved observing most groups in a discussion between themselves about spelling but in the context of moving the letters around to get them in the right place.

It was frequently observed that one child would tell another what to do and to discuss turns. It was observed that what had to be done as an intellectual activity was solved immediately, but how to do it took longer but still within 30 seconds. Two groups of children thought they had to type the words in, but before they had solved how to do it, someone had clicked and held down the mouse button causing the letter to move.

Children were asked, *'How easy was it to move the letters around?'* Most answered that it was easy. Ten children were also asked, *'What did you find out when you moved the mouse?'* Most referred to how hard it was to control the mouse. A teacher thought click and drag in the task had an educational advantage because it avoided children writing, and another teacher observed that children were quick to use it in comparison to using the school computer because they have to click and drag to mark out text.

Ten of the children interviewed were quite clear about what they had to do for this activity, which was clicking and dragging letters into boxes. But 5 children described varying issues regarding the clicking and holding down the mouse as opposed to, 'just clicking it like that computer over there', and also the task was hard, 'because you had to get the text into the right place'. The comment suggests that the motor task difficulty might be unconsciously perceived as being related to the intellectual task. One child liked the task because, 'I like to think what they could be.' This comment may suggest a potential for physical mouse activity to be related to forward thought, a projecting of what might be through the manipulative activity. The observation notes suggested children had no problem with understanding and achieving the task. Most discussion was about how to spell the words and suggestions on which box to put the letters.

Teachers did not comment on any difficulty children might have had 'Very quick even though the least able were using it.' But they were quite clear that moving objects was a desirable activity especially from the point of difficulty for young children to identify required letters amongst the QWERTY keyboard and difficulty of typing text. The advantage was 'That's the sort of thing they like doing. They're also in control.'

Activity 2 was a variation of Activity 1, applying the same click and drag task in a different context of moving planet images into pockets. All eleven respondents except one were observed to be clear about what they had to do right away. Children recognised that the icons got bigger when they were pressed, a feature which was actually a mistake in the programming.

Most children were observed to have no difficulty in clicking and dragging the mouse to put the icons in the boy's pocket. Those children that continued to have manual dexterity difficulties appeared to be put off by the time it took to complete the task and when one set of icons was completed, jumped on to the next activity screen without following up the other two tasks.

Where a group organised themselves so that each child put one star in at a time, a large amount of their time was spent in controlling the manipulating activities. They did not clap or even say a word.

It was observed that children with the mouse, busily involved in clicking and dragging, did not have a hand free to clap.

In reply to the question '*What did you find out when you moved the mouse?*' all answers from children involved issues of manipulation skills and nothing to do with the actual musical task.

From the observations the effect was enjoyable, and appeared to be an end in itself for some children. One child described the need to 'let go' of the icon in the pocket. Another child described a problem that, 'sometimes it [the mouse, the object?] gets stuck where the mat comes to the end. I make it all dizzy.' The child is graphically describing two features of problems encountered when moving objects with a mouse. First, as confirmed in the observations, it is clear that, in some circumstances, such as long distance moves of the mouse, i.e. dragging a planet icon from top left to bottom right, 'the mouse is required to be lifted up'. The reason is that the distance to be moved is more than the distance of the mouse (centred on the middle of the mat) to the edge of the mat. Second, the apt description of the wild movements of the object while the mouse is being brought under control as 'dizzy', leads one to be reminded of the need to be aware of a child's point of view. For a child, not only does this design problem detract from the main task, but might also be intensely pleasurable, or frustrating or even humiliating in a group situation.

Teachers were pleased with this task and thought it was easy for children to move objects round. 'They become involved. The minute they are doing it they become involved.' One teacher said, 'It doesn't hinder them. It increases fine motor control. It improves. I wonder if that is why Max [a pupil with motor problems] was going off the top [enjoying the task to the point of over excitement]?'

Teachers thought the click and drag was easy to use because of Apple's single mouse button. This interface was much more friendly for children to use than current computer programs. 'The worst that can happen is that you go to the previous activity or start again.' Another teacher reported, 'It increases fine motor control. It improves [their skills].' 'They are discussing the task as well' and, 'I think it helps because it focuses them on the objects.'

Activity 3 During this activity most children were observed to have no problems with clicking and dragging events. It was an enjoyable activity and created a constant stream of creative discussion how and what to do. Children engaged in 3 separate choices: putting instruments in the icons, playing the sound and moving them around.

Children made an issue about deciding on further choices of icons to create different sequences. One group said, 'Have to force it out.' This is a response to the fact that children cannot take things out of the pockets unless another is put in, 'forcing it out' after the first sequence is complete.

Children said, 'This time it was easy.' Children were observed to have no problems in moving objects and discovering all three aspects. One child uttered 'Weeee!' while moving an item.

Eight children interviewees were asked, '*What did you find out when you moved the mouse?*' All the responses related to the operations of the mouse and not the learning taking place. Children interviewed unanimously both liked 'moving things around' and found it easy to do.

One teacher asked, 'How do they know they've got 3 [possible kinds of choices of movement]?' The answer is that they have an audio message, but this forms one sentence as the activity screen appears, before children start exploring, and the message is not repeated.

A teacher made the point that 'I know that moving the things into the pockets is important but the end product is that they pick the rhythm. So I think I would have to explain to them how the thing worked and what they were.' Another teacher commented, 'Sometimes there are missed learning opportunities. Sometimes I am half-and-half on learning discovery and demonstrating using an analogy. If you don't tell them, they haven't anything to choose between.'

Another teacher commented on the range of tasks that could be performed using the click and drag mouse: 'They have two things they can do; it plays then you can also swap places. I don't know if it is an extension or a confusion. They were getting all the space things in. I think there is a problem with this that there should be the words on top they have forgotten, also they repeat that sequence, that particular pattern, they can only repeat it by changing the order around.'

On reflection, perhaps there is a case for 'small changes in activities' which might be based on providing children with simpler examples of tasks so that there is achievability at lower skill levels, then a progression in terms of intellectual and motor activity. But woven into the sequence there is a need for continual development and build up of expectation and excitement of some new event.

Activity 4 This activity required a more sophisticated set of control movements. Children had to choose an object, which then turned into a beater, and then click and drag it to make it operate on another icon. The beater then disappeared, but by clicking on the object a note could be created. In addition all the icons could be 'clicked on' by the now invisible beater. An additional form of movement control is available: if another icon was dragged into an icon that was already occupied, then the old sound icon would 'pop out'. There was generally observed to be more of a pause before children began making this work, but they went straight to it with constant clicking and dragging plus clicking of the beater. Children were surprised at the sudden appearance of the beater and concern over the disappearance of the instruments and the disappearance of the beater.

Out of 27 replies to questions related to mouse issues, the majority of children quickly found how to make the tunes. 'It was pimps [easy] and exciting.' Children discovered 'You could make your own songs and you could quickly exchange them.' Speed and ease and creativity are the themes running through the responses. Children were not disturbed by the disappearance of the beater as might have been expected. In fact, surprise was an added bonus 'Surprised that I found that if you cleared all the instruments [from the top line and put them into the icons] it would make them play. It felt very good.'

Children were asked, *'What did you like about using the beater stick?'* All enjoyed it and thought it was exciting and fun. One child answered, 'That you could move these into the star, moon, and sun and make the same noise.'

Teachers made the following comments on the operations of the mouse: 'I think this is OK. It is all going to depend on a good mouse. If I want to get from there to there it is quite a long way.' And, 'I don't think you can answer everything in the program itself. I think it would be in the teachers' notes to suggest.'

'Would it be better to point out things and ask children to each have a go at a screen? It's more valuable on a teaching point or a learning point if each person has a go at one screen, but would they lose interest?'

The reason for the lack of concern about the beater disappearing might be provided by the teachers' observation that: 'This is maybe where first time round they investigate. Then the second time you may have it more directed with questions with which instrument sounds like the sun or moon. I think there is a lot of potential there. There is surprise but equally the potential for in-depth work. Yes, I like that. Shame the beater is not on the screen.'
Another teacher commented, 'I think it needs the beater on the screen. I quite like the way it appears when you get it in the right place.'

In terms of extra potential of the open nature of the operation of the activity, a teacher suggested: 'As a teacher I'd make a little card. You could show the whole group and then ask if they can make some more up on the their own. You limit by explanation on the screen. You could write a poem and create the sound effects for the tune.'

On reflection, from observations and from just listening to the Minidisc digital audio recordings, it seems that if children are confused by the disappearance of the instrument icons, they are also intrigued. Children were fully involved here, in moving and action and holding the mouse button down.

Activity 5 The researcher's observations were more critical. Of 11 observations, there were none of the usual comments about chat. Children were silent and appeared to be struggling, clicking around and not getting anything out of it. Some children were taking a star to the instrument. If the star was moved first the sequence failed to work for a few moments. One child called out, 'Bright star in Bethlehem, Wake up time.' It was possible to put a star over the back button and jump out of the activity. It was also possible to stack instruments on top of each other and so go off-task by making this an activity in itself. The stars jumped around if children kept their hand down on the mouse button. Children could not remember where they put sounds once the stars moved around. (Perhaps this is like the game of finding the pea under the 3 tumblers trick?)

From a total of 27 replies to children questioned about the control of objects, all children knew what they had to do and could achieve the task physically, and most children appreciated the similarity to the previous activity. The attractive feature was the tune that played after the sound icons were all placed inside the star icons 'Same as the other one you could make your own sound and move it around quickly. It would do it by itself. Not like in the last one when you had to push it down.' The surprise was appreciated too 'Quite funny. You move them around and suddenly it makes you jump when it makes a sound. It is a bit difficult. It gives me a shock. It is a bit strange.'

Six children answered the question, *'What did you find out when you moved the mouse?'* Most responses referred to the operation of the mouse but there was little comment on the confusion caused by the mouse itself. Children do tend to understate problems they encounter (Crook, 1992).

Teachers pointed out the confusion caused by the mouse movements as children put the stars into the instruments when the programming requires that mouse function is suspended:
'They don't know whether to put it in or take it out.'
'I actually thought that me moving the arrow actually caused the noise. That is what I thought until I moved here and another sound started playing. I hadn't connected that it played in a sequence. I was moving this around.'

Teachers thought the activity was a little strange too 'I think I'm confused. If I move to the star it moves and my expectation is that pitch would rise. Now I'm clicking on star burst I'd expect it to play the sound.'

Another teacher also thought that moving the object around hindered understanding: 'I think it hinders the task. I didn't understand what I was achieving. I certainly didn't know when I moved it [the mouse] it was going to play the whole thing, because it was so slow. I thought that every time I moved the mouse it was actually clicking on this [a star icon] and I thought I was going to get the instrument icon down. The picture ought to appear underneath.'

Activity 6 Most points about the interface have been made in the other sections above. Children were observed to find difficulty at first playing the tune at the right speed moving and clicking the mouse. However, there were only 9 responses from children about ease of use. This was possibly because there were no other issues arising, as it was so clear, easy and trouble free to use. There were many more responses to the screen design and sound element (17 and 16 respectively). Children were only required to click, not move objects around. However, children reflected on the number of different responses to the several elements the activity was capable of: 'It would sing some music. You had to do the same thing. It could make noises like 'La'. When you pressed on that you could get the [whole] tune.' The responses were positive and clear. No one child was able to sum up all the range of possibilities.

The large size of the Jupiter icon made it easy for the mouse to be moved over and rolled-over to start another sequence and this may have helped the repeat process.

So much was going on in these observations that a clear pattern was not observed, only that the freedom to repeatedly go back and forward having listened to the Jupiter tune and then trying to play it themselves was fully explored.

Eight children were asked, '*What did you find out when you moved the mouse?*' Most children referred to the ability to use the mouse to get the tune.

Children were asked, *'What are the different things you can do with this task?'* They were able to list the things they could achieve.

Teachers commented on the accurate use of the mouse, that nothing seemed to go wrong and the importance of the ability to go back if they have missed the instructions. The flexibility was appreciated.

Teachers were asked, *'How does this task differ from the previous task?'* The responses were 'You have a specific challenge. You are holding that tune then find it. The other element given is a challenge, a specific challenge, a beginning or an end. This is so finite. If you have copied it what do you do now?'

The observations recorded problems with moving the mouse when they found the mouse difficult to move at the right speed to keep up with the tune and that Jupiter icon was so large they could easily roll-over it and start the sequence again by accident.

The Story Activity Observations regarding the moving of children into the house suggested it is easy to achieve but appears to have emotion attached to it. 'They disappear before they get into the door. It feels like you are moving someone else. Like they are using my feelings. They haven't got any of their feelings; they are using my feelings. It does make your hand feel funny.'

Most of the children that were observed appeared to be testing to see if holding down the mouse button caused the stars to be moved or made them disappear. They had difficulty with Starcatcher disappearing at the end of the story.

There were 33 responses from children to questions in this area. Most responses relate to the fact that children were trying to click during the storytelling when they were not required to do so. There was confusion caused by the apparent relationship between clicking and disappearance of stars (part of the storyline).

Children were asked, *'What they found out when they move the mouse?'* Children commented on how the child icons disappeared and that they went through the doors or windows. There was some apprehension of moving children round because it was not nice, they were vanishing and the house looked ghostly and dangerous. This was the only screen where the manipulated icons of human figures not inanimate objects.

Teachers made comments about: 'They don't see themselves as going into the story [with the icons]. Children experience it as observing it from outside like a programme on TV. They observe themselves like the third eye – another person watching it.' 'Children are expecting to do something to catch the stars with the mouse [Story Screen]. They are not used to just watch. They expect something to happen all the time. They expect to be in control.'

A teacher reacted to the click and drag element: 'I think it is a lovely idea. Whether they empathise with them I don't know. Do you have to take each of the children?' (Yes, they each take a child). The observations confirmed the confusion children had with previous uses of the click and drag into the story which was so limited in relation to other activities, and this feeling of frustration was compounded when the story itself was a passive experience not requiring clicking or moving objects.

Song Activity Observations covering mouse clicking during this activity have been discussed in sections above. It was observed that children were clicking on the words as they were highlighted. Otherwise there was no actual problem, the activity focussed on singing and all children were fully involved. Anticipated issues did not arise, perhaps because clicking on the narrow icons only had to be done once or twice to achieve the task.

Children were asked, *'What did you find out when you moved the mouse?'* Fifty-nine replies were analysed relating to, Criterion 7: Is the control of movement of an object easy for small hands to achieve?

This activity only required children to respond by clicking the mouse button. The issue here was the size of the icon at the beginning of each line, and the accuracy required of a child manipulating the mouse into the small area of the hotspot and then holding the mouse still to engage the click action. Ten responses suggested there seemed to be little difficulty: 'It's fine. It's good. It gets the song to going. Very exciting.' Teachers were in agreement: 'That's the way they learn songs, listening and repeating at this age.' 'It's good. They are much more likely to click rather than be told to learn.'

Of ten children, who were all asked, *'Tell me what it is like making the mouse move things round the screen?'* 4 said, 'exciting', 3, 'weren't sure', 2 said it was 'all right', and one found it 'difficult'.

If the concept of movement is widened to consider the highlighting of words on this page then the teachers' responses were positive. They thought that children were encouraged to read but splitting the syllables would have been an advantage.

5.5 The teachers' control panel

Teachers were asked a range of questions around the hidden control panel which allowed the teacher to select in theory 60 activities, 10 episodes of the stories and 10 songs from the original 10 broadcasts. In the Research Tool, one story, one song and 6 activities only were active. However, the teachers' control panel did demonstrate how these selections could be made. Table 5.1 lists points to which teachers were asked to respond:

1.	'They say that because you, the teacher, can switch sections on and off, the software puts you in control.'
2.	'How would this screen help you organise classroom activities and learning?'
3.	'The authors believe the control screen allows you to organise work for different ability levels in the class.'
4.	'Would you find this (control) screen easy to use yourself?'

Table 5.1: List of teachers' control panel issues presented to teachers for comment.

This group of questions were designed to reflect Criterion 10: *Is the totality of interface activities in a product capable of flexible organisation by the teacher to facilitate learning?*

To this group of questions, 4 replied immediately 'Yes.' The majority of teachers gave varying degrees of positive response. All teachers thought it was important to be in control and 'We should get from these what we want to get.' One teacher commented how an existing CD-ROM (My World), with an open menu method of defining levels of complexity, could be changed by children. The problem was that the teacher might set the level and tasks, only to find 'In ten minutes they're doing something different.'

Teachers thought they could organise CD-ROM multimedia work differently if they had the high level of control provided by the teachers' control panel. Prompted about what kind of different work, the response was 'I can put children on different levels according to their ability' and '...because you could plan progression.' Another said, 'Yes and also to reinforce things.' Also, 'You are not just setting up levels on different activities. You are setting up different activities. You have a lot of options.'

One teacher thought that it was still hard work having to listen through all the items and that a print-out was preferable. (This is an option in one area of the control panel.) 'It is easier to use but you really would need the teachers' notes too. You have to have the terminology in the

National Curriculum so you'd know whether it was listening or speaking, it was rhythm or pitch, whether it was recognising sounds.' The control panel does not define activities according to these categories.

Regarding the two secret keys, teachers thought children would eventually find how the secret keys work, but that they would be good about not touching them. The temptation was reduced by making the keys a bit difficult to remember.

Teachers were also asked, '*Does the organisation of the software fit in with everyday classroom practice?*' All 5 teachers answered in the affirmative. Concern was expressed about the irritation of the sound, but it was pointed out that the teacher could control the sound simply from the teachers' control panel not through the computer's system controls. This was thought by one teacher to be an added advantage.

One teacher summed up the advantages: 'Yes in that you can leave children to get on with it so you don't have to be there all the time explaining the next activity. They will find their way to and fro quite quickly and you will have limited them to what you will have wanted them to do, so you can say you want every child to spend ten minutes on this machine then you only have one activity available to them. You could fit it in a day when you had a day with lots of other things going on. Or you could make it a much longer activity and know that you only wanted two groups of children that day to thoroughly go through it.'

It is important to reflect that teachers' control panels in CD-ROMs have improved since this study has been carried out, notably in Riverside Explorer (AUCIE, 2000).

5.6 The analysis of the evidence

The aim was to use the data to answer the main research question:

What are the design features required to improve the quality of computer interface interaction for 5 to 7-year-old children?

In this section the evidence was analysed according to the 10 Criteria or 'Rules of Engagement' listed in Table 4.1 (p. 144) in chapter 4. The first 4 criteria relate to standard interface design. The other six reflect on the innovative design features in the Research Tool.

5.6.1 Criterion 1: Are users clear about what task they can do with the interface?

The success or otherwise was gauged by the user's understanding of, *'What can I do with this screen?'* The conclusion from the evidence was that of all the different interfaces investigated in the main study: the simpler the task and the shorter the instructions, the easier users find the activity, as in Activity 1. However, there were also a wide range of variations and apparent inconsistencies in children's reactions to the other interfaces. In the opening interface, for example, there was a wide range of responses, and preferences for action. The responses appeared to be in conflict. According to Criterion 1 the opening interface has failed in its objective. Yet children found it exciting and they wanted to find out more and clicked 'everywhere'. The intention of the opening interface was to be open-ended and to give children choice, to engender mystery and excitement. Clarity was not the objective. However, further thought on how to manage the clarity of the 'mystery and enchantment task' rather than 'choice task' might inform an improved interface design. Criterion 1 was included because of its references in several multimedia design manuals though not necessarily applicable to educational multimedia.

The commentary in the section takes as its starting point the possibility that the simplistic definition of success – users being able to analyse consciously what can be done with an interface – was in itself unsatisfactory. Children do engage in reflective self-questioning during activities (Beard, 1972). However, the assumption even that adults engage in the process in a planned systematic and thoughtful way at the computer was equally ambitious. This criterion was a design guide for software, which was at the time not accessible through simple buttons and multimedia interfaces. The multimedia interfaces had not yet been conceived.

Users were now provided with a new kind of interface, not just a line of code, or text, or single function, or single image. Users were faced with a complex visual and audio image as well as the text.

There was also another design feature in the Research Tool – the ability to manipulate objects. *What can I do with this program?* was originally applicable for command driven (DOS) interfaces. In a Windows type environment, where the manipulation of objects was more intuitive, the meaning of 'do' has now changed. Previously 'doing' involved typing in words, positioning the cursor with the arrow keys and clicking. Later the mouse functionality allowed the easy positioning of the cursor. The evolution of the operating systems through Windows type environments, of which the mouse was part has hidden the real development –'do', now involved physical activity at the computer.

The 'doing' – manipulation facility in the Research Tool software design – had 3 effects:

1. 'Doing' was no longer an abstract cognitive process. Children did not have to think logically or create a mental model, even if at their age this level of abstraction was not to be expected.
2. Children did not have to read instructions or listen to instructions to make the computer respond.
3. Computers were capable of responding very quickly to a child's 'wish' to move objects, enhancing a sense of control through the sophistication of the windows type operating system.

'Doing' in its simple linguistic sense, as understood by the early software designers' understanding of metaphor, was now replaced by 'the real thing' in Lakoff and Johnson's (1980) meaning of the experiential metaphor. Children, using the mouse were in a holistic process that involved their mind and body physically in their 'doing'. The interactive interfaces enabled children to be children; they could play, talk, try again, make mistakes or just fiddle about. The effect was that the experience of watching children using an interface could look (and sound) like chaos. Logical events on a computer did not appear logical to children. Moreover, the cumulative effects of these developments meant the events were no longer in the control of teacher or parent, or even under the control of the traditional logical development plan of a designer. The 'sum' of the interface was greater that the designed parts.

'What can I do with this screen?' only made sense if interpreted with the manipulation facility as *'What might I do if I physically explore everything on the screen right away?'* The interpretation took into account children responding by clicking everywhere to see what happened and moving on quickly if something did not work right away. The software was no longer failing and did it matter that children could not remember more than two instructions in a sequence, because they could always return and have fun trying again?

To summarise the results from testing Criterion 1, the question may have become less significant in terms of its original context of cognitive processes in the light of the new media developments, especially manipulation of objects, that have taken place since it was formulated.

5.6.2 Criterion 2: Are users clear how to make the interface work?

A user asks, *How do I do this task?* The evidence showed children spent time answering this question out loud, speaking to themselves and to others at each interface in the Research Tool. They took variable amounts of time at each interface to solve the question. Children talked to each other to resolve this question. They asked the question, but out loud in the form of, *'How do I make it work?'* The question was resolved not by an internal, intellectual process, but as part of a pattern involving the help of other children and by a trial and error, 'try-it-and-see' technique. More significantly as in criterion 1, the 'try-it-and-see' technique was a physical process, i.e. moving the mouse, not an abstract intellectual process, indeed so was the resolution of the problem as posed by the activity.

The evidence also pointed to a clear distinction between the kinds of interactivity that involved users in fruitful and meaningful discussion using positive language, and discussions with varying negative expressions from boredom and frustration, through annoyance and simply moving on to another screen. The analysis of these discussions has been difficult: partly because the unusual feature of this software was the ability to move icons around not just click on them. In this context it was not surprising that *what is to be learnt*, i.e. musical patterns, was not necessarily the priority for users; *how it works* has to be resolved first. The difficulty was compounded by an assumption made by adults of educational software design that children should automatically be able to make an interface work first time. This assumption was made even though adults themselves sometimes have the greatest difficulty using the same commercial edutainment products.

Some confusion about *'How does it work?'* has also been caused by the software functionality of the computer being in its infancy (Activity 5). Clearly, disappearing icons, events that make unreasonable demands on memory and also multi-events without feedback cause the 'discussions of frustration'. Less forgivable was the unclear identity of icons and symbols.

Finally, it is necessary to comment on a third kind of discussion between children: talk that reflected the excitement of discovery and the appeal created by the changes in demand between one activity and another. The exchanges were about issues around the fine line between making procedural standardisation and clear functionality, but bore users – a point considered in more detail later in this chapter.

There remains the consideration that teachers liked the idea of discussion between children at a computer. The availability of computers in a primary classroom was limited and often children shared its use. The educational value of discussion to solve problems encouraged verbal and social skills. There was also a fine defining line between the discussion that was a working around of some complication in the software and a planned requirement that discussion should take place. For example, some teachers commented that they were quite happy that children were trying to work out the identity of the planets from the rather indistinct symbols, when the researcher was very concerned that they were not instantly recognised and the cause of the problem was the artwork briefing. To summarise the results from testing Criterion 2 the test results suggested the subtle possibility of 'designing in' discussion as a valid educational exercise.

5.6.3 Criterion 3: Are users clear about what is happening when they use the interface?

Users asked themselves, *What is happening? Why did it happen?* and, *What does this mean?* Users expected a simple feedback response. In the interfaces, especially Activity 5, which caused the most problems, children and teachers were confused as to what was happening and why. In these cases the feedback was insufficient or confusing.

Users may not have understood how the computer was carrying out the tasks. But there were responses, which the computer was expected to make and these responses became formalised after a very short time. The acceptance of features such as 'click and pop up' as the norm and 'click and drag' as something that was new, reflected the speed with which users got used to a computer program. The Research Tool worked in a different way to existing commercial products at the time, especially in the manipulation facility. The new facility did provide instant feedback of a new kind that needed time to assimilate both for the researcher and users.

Also as each interface acted in a slightly different way, there was a new challenge at each screen. These slight changes are suggested to have been a constant source of pleasure and involvement and enhancement of the quality of engagement. However, in Activity 5 both the initial action and the events that followed, broke all the expected 'rules' expanded upon in each successive previous activity. To have a tune play endlessly and automatically, as the result of no clearly defined action and with no real aim is a case in point.

Criterion 3 has as its assumption that there has been an event to which one feedback element occurred, because it was formulated for the early system software where an event was only a text based command line not a graphic image with many competing visual and audio elements. To summarise, with a multimedia interface came the need for a new holistic paradigm to formulate the synchronicity of a variety of visual, audio and tactile feedbacks. The successful interface was one in which questions become, *What are all these happenings? Why did they happen?* and *What do they all mean?* was understood by a child.

5.6.4 Criterion 4: Do users find it easy to navigate around the software product?

Users asked themselves, *Where am I? Where have I come from? Where am I going to?* The success of the criterion was the degree to which positive responses were received to these questions. In general, the design of the Research Tool was planned to overcome the issue of navigation problems, identified as prevalent in commercial CD-ROMs and sold as having educational value.

The evidence pointed to the main issue – that of becoming lost – endemic in many software products, which was solved by the system of switching on and off pages given to the teacher to control. This result was a simple and easy to use structure. If, as planned for the final production version of the Research Tool, teachers chose to switch on every element, 10 songs, 10 stories and 40 activities, users would require time to navigate through the product. But as each of the three sections; stories, songs and activities had a linear structure within each of the 3 elements, achieved by using simple backward and forward buttons.

In the Research Tool, during the school tests, all three choices on the opening screen were activated, but with only the story, one song and the 6 activities. There was no visual priority or other weighting given to one of these three elements. The proposition was that the coherent structure of the original radio programme and resources allowed children to gain an insight into whatever element they explored first and finally an 'overall picture'. In contrast, teachers suggested that the story should have been logically given as the first choice.

Where navigation can be said to have created a problem or an issue, it was to the extent that there was a clear policy to create an open-ended choice at the beginning of the software. The evidence from the opening interface questions pointed to a particular kind of problem that a conventional criterion for good navigation cannot satisfy. There appeared to be a conflict between the need for clarity and the need to create an open-ended experience.

The opening interfaces of the edutainment software delivered in the CD-ROM in Primary Schools Initiative (NCET, 1994) usually had a clear choice structure but were text not audio based. In the Research Tool this form of textual limitation to a child-centred approach has been removed and given to the teacher to manage, and been replaced by artwork which was intriguing and exciting to children.

To summarise this section on Criterion 4; through the thesis, the understanding of how adults' expectations of what an opening screen should do was broadened to encompass the possibility of 'being lost' in certain circumstances, as a desirable state in which to put users, where discovery, excitement and pleasure were harnessed as a learning event. The process included the following considerations:

1. A lack of clear didactic structure of the subject matter in the opening interface was desirable. There should be a clear structure but it could be hidden.
2. The software was allowed to reveal its secrets through reuse.
3. The depth of engagement inherent in computer games of discovering new things all the time, the so-called 'cheats': choices, variations, secret complicated codes that

need breaking to discover more. These operated on the borderline of uncertainty, pleasure in concentrated effort, discovery and finally resolution.

5.6.5 Criterion 5: Is the interface activity an enjoyable and absorbing experience?

This criterion is in the category of innovative design features in the Research Tool: criteria identified by the research as being of additional value in defining the quality of interface design. Two points are to be considered as background to criterion 5.

1. It has to be recognised that as the subject of the Research Tool is music. It was a popular subject for many children in the age group. The research must recognise the 'head start' in the pleasure and involvement inherent in the subject matter.
2. It was a conventional wisdom that children learn best when they were enjoying themselves. Yet one child's idea of a pleasurable activity was not another's. Learning activities cannot always be enjoyable, however well-intentioned. The evidence suggested the ability of individuals to find pleasure in tasks that might not appear to be interesting in themselves, but absorbed and involved users in concentrated activity.

With these two points in mind, the evidence suggested some features of the Research Tool interfaces may be said to contribute to achieving the enjoyable and absorbing educational experience which is the focus of the criterion.

Features inherent in games have already been identified in the previous section. The responses to the opening interface confirmed its ability to stimulate suspense, excitement and wonder. The excitement generated can be said to be clearly nothing to do with music, which for music teachers may be seen as a drawback. However, this followed the conventional radio technique of 'hiding' the message within a story. Some of the triggers to excitement and pleasure were known as conventional media techniques: non-realistic images, soft outlines, rich colour contrasts between gold and dark. However, the evidence seemed to suggest that the combination of the old communication codes of involvement and the new interactivity may provide the key to what was enjoyable and exciting from a child's perspective. The conventional triggers could be excessive. The evidence pointed to an overloading of attractive features. For example, an error was made through lack of understanding of the visual attention given to the largest star on the opening interface, which could have had a useful roll-over functionality. The significance of the cluster of attractive features of the boy, his pointing, and the audio and visual message of things to do were not consciously designed to have primacy on the screen. However, they did have an overall visual priority. It should have been planned!

The key textual and audio question, *Who is Starcatcher?* in the opening interface was not really recognised to be the focus of children's attention. The reason should have been understood; it was a clear question but the means of answering it were not clear to children. It was 'swamped' by the other multimedia events; the physical movement and control of the mouse was children's main focus of attention. Making it work, finding out what it would do dominated the activity. There was a satisfying instant response available from the three roll-over icons. The response was a combination of sound, text and visual (the glowing highlighting of the border). The result was confusion and the source of the problem was roll-over functionality with a high-speed response which allowed the blurring of one roll-over with another, a combination that might turn excitement into chaos.

The opening screen differed significantly from a conventional opening screen design. It was a design based on the researcher's experience of designing 'openings' of radio programmes which explore the ability to inspire, motivate and excite. Here, the quality of engagement analysed and managed from the first screen of a software product for '*total impact*' – a concept described in chapter 6 – could be a valuable method in future. Conventional multimedia production methods militate against the estimation of the total impact of an interface. Unlike film, a multimedia story board cannot fully convey non-linear functionality, though a story board is often used in the design process for many multimedia productions. However, multimedia production schedules require that the artwork and programming are only fully functional at the end of the process. At this point there are often so many elements to the product that the task of analysing effectiveness of one screen is not easy.

In regard to the other interfaces of the Research Tool, the evidence pointed to depth of engagement through pleasure and concentration generally being identified with the manipulation of objects that were presented as tasks in a clear and a rational way. Where the manipulation had no meaningful feedback, enjoyment caused children worry and confusion.

The evidence may be said to show that the ability to repeat the tasks was an element in the enjoyment. The reasonable assumption was that children were free to enjoy the repetition if they were successful in completing the task and able to solve the problem without criticism. The simple structure of the interactive task and navigation both facilitated this process.

The evidence of the success of Activity 6 seems clear and was commented on by pupils and teachers and in observations and therefore deserves a detailed assessment. The structure of the tasks arose from an attempt to simply transfer the radio script to the opening instructions. The sequence of: demonstration, simplified example, instruction to join in and try yourself are an application of the basic educational radio script writing 'design code'. It was arguably something with which children would be familiar. Therefore children could be confident of the task, with additional features of time to absorb the information through repetition. The instructions could also be repeated without going back to the previous screen. These were all features not present in other interfaces besides the opening interface of the Research Tool, features that were in the best tradition of conventional classroom teaching practice.

On top of the stepped, paced, clear introduction was built a level of interaction that has not been available to teacher or pupil before. New media has allowed for the analysis – the visualisation – the revelation of the structure of the music with the ability to repeat at will the discovery of the elements. Children have control. Also there was a further level of activity, an 'added creative and interactive value', of the hidden ability for children to reorder the notes in their own way – to play a different tune. All these elements within a recognised pattern of teaching structure made the activity a success.

The success of Activity 6 may be ascribed to the features, operating structure and content as above. However, they may be invoking more than a series of processes forming enjoyment as described by Csikszentmihalyi's (1992) eight processes (see p. 94) These were interpreted and expressed by the researcher in the context of children using the Research Tool interfaces as follows.

1. Children are confronted with tasks they can complete because of their empowerment. These same music tasks in a classroom situation have inherent problems of physical manipulation skills which are resolved on the computer.
2. Concentration is easily achievable for the young age group because, first, only three children rather than a whole class are involved. Secondly, the manipulation and hand-eye co-ordination requirement stimulate focussed involvement.
3. and 4 (There are clear goals and There is clear feedback). It is worth noting the similarity between the language and the processes in this context and interface criteria terminology in the Standard Interface Design Practice above *(see Table 4.1, chapter 4, p. 144)*
5. Children appear to be removed from the 'worries and frustrations of everyday life' in their own terms, i.e. the teacher, the rest of the class. The absorption may come from in making the 'thing' work successfully with their friends in a comfortable classroom atmosphere.
6. The experience may allow children to exercise control over their actions and is enjoyable.
7. Concern for the self disappears, which can be intimated from the lack of evidence of conflict between children and the general atmosphere of co-operation, discussion and positive approach to problem solving. There is no evidence to suggest that children gain a stronger sense of self-emerging. The research has not specifically measured this element, only to the extent that there is a consistency of the positive responses to the overall experience.
8. Csikszentmihalyi's references (p. 49) to the loss of time experienced by those immersed in pleasurable activities were similarly not measured in this research.

Activity 6 of all the activities contained the greatest collection of these 8 features, but the result was not just enjoyment, the quality of engagement was enhanced. When the traditional codes of involvement and the new interactivity were combined successfully they form a concept of the 'total impact' of an interface. Whether numerical data would give statistical support to a general impression that most of the 8 elements appear in Activity 6 but not all or in different combinations in the other interfaces was quantitative research beyond the scope of the present thesis.

To what extent the general experience of the interfaces was educational was not so clear. The focus of the research was not to find out what had been learnt from the interfaces. The evidence pointed to confidence expressed by the teachers that further use in the classroom would achieve its educational aims, that music learning would take place, but that it would require input from the teacher. However, teachers made a positive response to the amount of control and involvement in its use.

To summarise the results from testing Criterion 5 this section has sought to use the evidence to answer the question, *Is the interface activity an enjoyable and absorbing experience?* As far as the opening interface and Activity 6 was concerned the evidence pointed to an overall positive answer which was certainly, 'yes' and to the other interfaces to varying degrees of success. By using the criterion as part of assessing the 'total impact' of an interface, design planning could be refined to incorporate traditional and new techniques to absorb children in an enjoyable educational activity.

5.6.6 Criterion 6: Does the interface activity engage users in concentrated activity through movement?

This was proposed as an innovative design feature in the Research Tool. The evidence suggested that control of movement was a prime instigator of concentrated attention and activity. The constancy of references to children's use of the mouse was a central feature in the research. The movement was not of the 'click and something appears or disappears' functionality expected by children. The 'click and drag' involved children in more overall concentration of attention, first, in learning new manipulation skills and second, in completing the task.

The evidence did not directly relate to the findings reported in the literature relating to visual search and hand-eye co-ordination. Techniques using an eye camera would be required to test the hypothesis that focus on attention through movement in the Research Tool interfaces was facilitated and/or accompanied by physiological 'focussing' that included reduction in the saccadic eye movement, narrowing of eye search pattern and reduction in the size of the foveal oval. However, the literature did indicate that these processes took place when movement occurred.

The design of the screen interfaces of Activities 1 to 6 was specifically arranged with this manipulation as the core activity. These screen layouts with their white backgrounds and functional structure were patently not a page or a graphic image as in the opening frames of the story interfaces.

To summarise the results from testing Criterion 6, there was evidence that the visuals of the interfaces alone did not give a clear indication of the activity to be performed. However, the absence of written instruction avoided reading problems and a visual distraction from the main task. Another feature enhancing the quality of engagement came from the audio messages with their encouraging message and tone, with the physical manipulation and the ability of repetition regardless of instructions and despite making mistakes. The learning objectives of the screen were not made clear – that is the role given to the teacher. The design gave a child the freedom and the license to repeatedly try, explore, test, and investigate.

5.6.7 Criterion 7: Is the control of movement of an object easy for small hands to achieve?

This criterion was also proposed as an innovative design feature in the Research Tool which has been applied to take into account problems observed by children in the early research phase, problems such as using a large mouse, adult computer layout and desk design.

During the main study the researcher's computer was used but the desk size and position could not be controlled. However, the keyboard was removed from in front of the computer – the normal configuration. This allowed the mouse to be in front of the computer, not at one side as is normally the case, (even when the keyboard is not used) and with space to rest the heel of the hand on the desk. The result was that children did have more freedom to move the mouse on the mat than usual. The mouse was an adult size, though the Macintosh mouse (with one button and a smooth round design) might be easier to use than the average PC model.

One feature of the Research Tool had been adapted during the first pilot. It was observed that children had difficulty dragging objects for long distances across the screen. The cause was the relationship of the length of movement across the screen and the length of journey the mouse has to travel across the mat. The situation might be resolved by training as the mouse can be lifted and replaced in the mat centre. It was considered to be beyond the ability of children to lift up and grip an average-sized mouse and there was no time for training. The problem was solved by repositioning the icons on the screen and testing the mouse moves required.

To summarise the results from testing Criterion 7, as a result of understanding the significance of observing the need for control of movement of an object, provision could be made easy for small hands to achieve in most of the interfaces. The story interface click and drag problems were not just caused by the mouse but by not specifying precisely the area to which the objects could be deposited. However, the small size designated for hotspot areas made fine movements of the mouse more of a task for children to perform.

5.6.8 Criterion 8: Do small changes in the design of screen activities stimulate involvement of the user?

This criterion, an innovative design feature in the Research Tool, arose not out of the early pilots and reading but originated in the creative process of designing the Research Tool. The interface designs were a response to the classroom tasks featured in the radio programme and the teachers' notes. They also explored the capabilities of the software which at the time were in their infancy. The order of the activities was changed after the first pilot, putting the simplest activity first followed by the other activities in increasing order of conceptual complexity.

The rational argument for the practical ordering of slightly different tasks came from two sources in the literature review. First, the physiological aspects pointed to the tendency for the human eye to become less efficient at recognising features in similar images as they are repeated. Second, the advantages of pleasurable anticipation, testing of skills and concentration showed by Flow Theory. The evidence from this criterion suggested small changes do enhance the quality of engagement. In addition, there was a general concern at the time amongst educationalists, and expressed as a key element of the MENO Project at the Open University, that the structure of 'multimedia programs or sometimes the lack of it, affected learners' comprehension, often adversely' (Laurillard, 1994).

The structure of the Research Tool was contrary to the conventional methodical CD-ROM design structure with its requirements for ease of navigation through visual and textual conformity. In these CD-ROMs, navigation buttons and layout meant one page was much like another. The result was a great tendency to click to go to another screen to relieve the boredom and, in many cases, the 'boredom clicking' was compounded by little interactivity within any one page.

To summarise the results from testing Criterion 8, the Research Tool may be considered chaotic according to the current multimedia design. However, this criterion tested the quality of this style of CD-ROM to continually intrigue and involve users. The researcher considered that the evidence showed it was through these small changes that engagement provided a stimulus to involvement.

5.6.9 Criterion 9: Does the interface have multi-functionality within an activity creating flexibility that enhances the quality of engagement, but does not cause confusion?

Another innovative design feature in the Research Tool, which from the evidence, revealed there was a clear distinction between multi-functionality that caused confusion, and multi-functionality that was absorbing and enjoyable. Activity 5 in many respects has the unorganised excitement of the opening interface, but the former did not provide the feedback of the latter. If the technique used for instructions in Activity 6 was applied to Activities 3 and 4 it is reasonable to think that their multi-functionality would have been exploited more quickly by children.

To summarise the results from testing Criterion 9, it was considered that this criterion has validity in focussing attention on engagement as well as a logical series of events. It was a tool for 'building in' fun and pleasure as added value and making these instinctively recognised vital elements less arbitrary and uncontrolled. Conversely, the logical design process was enhanced, because there was a counterbalance to the boredom that was associated with its methodical approach.

5.6.10 Criterion 10: Is the totality of interface activities in a product capable of flexible organisation by the teacher to facilitate learning?

This innovative design feature was a criterion separate in all respects from the other criteria as it relates to teachers alone. However, it has an integral functional relationship to all the other criteria. Teachers are the instigators and mediators of learning. If a teacher is not wholly informed, conversant and able to choose the elements of the software's content, the other criteria would have very little chance to be met. The main study showed it was possible to create an effective teachers' control panel interface to meet this criterion. Teachers were universally in agreement with the advantages of this new design feature. The desirability, the ease of operation and educational value were considered useful by all the teachers interviewed.

The innovative nature of this screen design did mean that teachers had never come across the level of control before (the ability to look at all the resources quickly and easily due to the organisation in segments within the teachers' menu). They saw its advantages over existing designs. Their experience was the greatest difficulty in finding the content of the edutainment CD-ROMs delivered in the CD-ROM in Primary Schools Initiative. For this reason, organising a valuable learning experience was also difficult.

To summarise the results from testing Criterion 10, the teachers' control panel was contrary to the style and expectations of multimedia structure. The concept had much more in common with games design where users goes into a bank of further information (e.g. weapons) to add to the main action. It was possible that a future development of this principle might, as children have become familiar with multimedia, be told to go into the 'teachers' area' which might be called 'your learning bank' to pull out their own learning experience under guidance of the teacher. However, in the context of this study teachers would have had to go through the planning process themselves to gain a fuller picture of the operation of this facility.

5.7 Summary

The tabulated summary of results of the criteria informing the research question:

What are the design features required to improve the quality of computer interface interaction for 5 to 7-year-old children? is listed in Table 5.2.

Criterion	Features that improve the quality of interaction
Criterion 1: Are users clear about what task they can do with the interface?	Interface features that are simple tasks with short audio instructions are clearest. There are benefits from 'sequenced constructions of audio instructions'. The Windows interface is now intuitive and 'doing' – using manipulation – means a child can respond directly. However the quality of engagement is enhanced with this feature.
Criterion 2: Are users clear how to make the interface work?	Interfaces especially using manipulated objects are explored by 'try-it-and-see' technique prompting the question asked out loud by children '*How do I make it work?*' and discussion using positive language, when successful and discussions expressing boredom when frustrated. There is educational value in this process.
Criterion 3: Are users clear about what is happening when they use the interface?	The successful interface is one in which *What are all these happenings? Why did they happen?* and *What do they all mean?* is still answered successfully by the child. Graphic images capable of manipulation and with visual and audio elements challenge users. With a multimedia interface comes the need for a new holistic paradigm for design.
Criterion 4: Do users find it easy to navigate around the software product?	An opening interface that is intriguing and exciting to children is a possibility by giving control to the teacher to organise simple navigation, but there are issues about the uncertainty caused.

Criterion	Features that improve the quality of interaction
Criterion 5: Is the interface activity an enjoyable and absorbing experience?	Interfaces that are enjoyable and absorbing can be designed using ideas inherent in radio programmes and in computer games and potentially given a formal structure using Flow Theory.
Criterion 6: Does the interface activity engage the user in concentrated activity through movement?	Interfaces that give users control of movement in terms of manipulation of objects is a prime instigator of concentrated attention and activity.
Criterion 7: Is the control of movement of an object easy for small hands to achieve?	Interfaces can be made easy for small hands to achieve in most of the interfaces, but early testing is essential to overcome issues that may arise.
Criterion 8: Do small changes in the design of screen activities stimulate involvement of the user?	Interfaces were reordered putting the simplest activity first followed by the other activities in increasing order of conceptual complexity. Evidence from this criterion suggest small changes do enhance interaction.
Criterion 9: Does the interface have multi-functionality within an activity creating flexibility that enhances the quality of engagement, but does not cause confusion?	Interfaces can have multi-functionality that causes confusion, and multi-functionality that is absorbing and enjoyable. This criterion may have validity in focussing attention on the quality of interaction as well as a logical series of events.
Criterion 10: Is the totality of interface activities in a product capable of flexible organisation by teachers to facilitate learning?	An effective teachers' control panel interface can be created to meet this criterion.

Table 5.2: Design features required to improve the quality of computer interface interaction for 5 to 7-year-old children.

The criteria in this chapter have been tested thoroughly and they have proved to be largely a set of useful tools for analysis informing the research question. There were two qualifications. First, with hindsight, adapting Csikszentmihalyi's (1992) study techniques might have provided a more thorough analysis of what constitutes enjoyment in computer learning. Second, the definitions of interactivity could be reassessed. Interaction as the process of control and feedback (Cotton and Oliver, 1994) and participation in terms of frequency of interactions, choice available and 'significance' (Laurel, 1991) did not describe fully the interactivity of the mouse manipulation processes that have since become available for common computer use. Nevertheless, these two qualifications highlight the results of the main study that a new holistic paradigm was required – a coherent relationship between a child and a computer – formulating the features of a deeper quality of engagement achieved by using a combination of: open ended tasks, audio instructions, physical manipulation, 3-D interface simulation, concentration, pleasure, small changes in tasks and hidden elements to be discovered. This was a relationship made more effective by the proposed features of optimum computer desk and screen configuration. The paradigm of whole child-computer relationship proposed in this thesis was given its holistic coherence by the ontological nature of the *container* metaphor *(see chapter 3, p. 106)*. In the next chapter results of the criteria informing the design features to improve the quality of interaction are formulated in to a practical method of developing multimedia products embodying the new paradigm.

Chapter 6: Improving the quality of interaction

6.1 Introduction

The chapter is a reflection on the research question in the form of a practical method of improving the quality of computer interface interaction for young children. The results of the investigation into **What are the design features required to improve the quality of computer interface interaction for 5 to 7-year-old children?** were formulated as a selection of intellectual tools tentatively called *the total impact assessment toolbox. The total impact assessment toolbox* was a practical, day to day method, not a theoretical model, for discussing, planning, and developing a new multimedia product with a coherence that offers a greater depth of engagement. The *toolbox* metaphor incorporated *the briefing tool, the educational task tool, the visual task tool, the manipulation task tool, the classroom context tool, and the teachers' control panel tool.* The tools in the *toolbox* embody the new holistic paradigm. After describing the *toolbox*, the underlying concepts and principles were briefly summarised confirming the contributions to the *toolbox* from the literature review *(Section 3.2: IT in primary education and Section 3.3: Interface design)* and the main study *(Section 5.6: The analysis of the evidence)*.

6.2 The total impact assessment toolbox

The wide ranging sources in the literature research in chapter 3 and the results from the Research Tool converge around one central principle: the need for practitioners to be alert to the interrelationship of physical and physiological factors between children and computers in classroom environments that can be used to enhance the quality of engagement. The *total impact assessment toolbox* is a practical guide for producers and developers for everyday use in the busy workplace. It is not just meant to be a simplified summary of the research. The terminology is also intended to be child-like. The effect is to give the whole design process as far as possible a child-centred approach with the specific purpose of maintaining the focus on the client.

The first advantage of the *tools* in the *toolbox* is chiefly in their child-centred approach but also their brevity, pages of systems-style analyses are avoided. The second advantage is that the *tools* focus on key elements of the product.

The briefing tool

A brief is a common feature of any job to be tackled effectively. In the first draft of the brief, the conventional planning methods of educational product design, such as the factual content of what has to be learned, the age of users, and the National Curriculum content, will be prepared in ways which are appropriate and familiar. In addition the conventional plan should include two important elements:

- The product must be trailed with children early in the production process to identify basic errors in interface design.
- The teacher should have a method of ensuring comprehensive control over aspects of configuring the product for classroom use.

However, using the particular language of the briefing tool, the first draft was turned into a language that focussed the software development team to the needs of the 5 to 7-year-old child. A series of child-centred questions were proposed. These are listed in Table 6.1 below; '*you*' refers to the designer/educationalist, '*me*' and '*I*' refer to the child end-user of the software being developed.

The briefing tool			
1	What is the single most important message you are trying to tell me?	6	Is the mouse difficult to use?
2	What other things are you trying to tell me about?	7	Is the next task a bit different? *(Are tasks progressively challenging?)*
3	Can I complete what you are asking me to do in a normal classroom session?	8	Is it enjoyable and fun to use?
4	Can I understand the voice instructions?	9	Are there secret things to discover?
5	Can I move things around the screen?	10	Can I go inside places and things? *(Will children benefit from using a 3-D interface?)*

Table 6.1: Total Impact Assessment Toolbox: questions that assist the briefing process.

It was suggested that a similar child-centred approach could also be employed in the next three sections by using the appropriate level of language – of a child – to the product being designed. In this way the focus of the appropriate level of complexity may be more easily achieved.

1: The educational task tool

The educational task tool in Table 6.2 was not intended to test whether children were aware of their own learning, but was presented as a self-questioning didactic tool – familiar to teachers to be critically aware of their actions – that should also be used by practitioners to ask questions which might start the design team on a comprehensive process of sensitisation of their own preconceptions of the educational value and clarity of the instructions in the product. '*This*' refers to an opening screen image, '*I*' refers to the software user.

The educational task tool
1. Opening screen: 'This looks exciting', What shall I do now?', 'Is it fun doing this?' 2. Audio instructions: 'What is Mr/Mrs computer asking me to do?' 3. Text instructions: 'Can I read those words out aloud now?' 4. Manipulation: 'Moving those things around could help me learn more?' 5. 3-D screen design: 'Can I look down on information in 'rooms' so I can search for information and find my way round more easily?' 6. Order of tasks: 'Is the next task more challenging that the last?'

Table 6.2: Total Impact Assessment Toolbox: questions that assist educational value and clarity of instruction.

Software designers should talk to the screen in the first person, putting themselves in the position of the child user. This method, apparently fanciful was a serious attempt to follow Piagetian principles. Piaget identifies 'talk and action' as a key element of learning through activity – children give the object that moves the attribute of 'being alive' (Turkle, 1984). Evidence from testing the Research Tool confirmed children do talk to the computer while they work. The method encourages adult designers to be aware of user's perceptions.

2: The visual task tool

The visual task tool in Table 6.3 and associated aspects are grouped around the subject, 'Is it clear what I have to do just from the pictures on the screen?' A downward viewpoint and images drawn in perspective have an advantage in ease of recognition. The technique of talking aloud to the screen whilst focussing on the screen visuals is a valuable aid to raising self- awareness of potential problems. *'I'* refers to a user, *'you'* refers to images and human figures that are part of the interface, 'rooms' refer to the downward viewpoint and images drawn in perspective.

The visual task tool	
1. How do I make you work? 2. What are you? 3. Who are you? 4. What can I see is happening? 5. What did I see happen? 6. What does this mean?	7. Can I see where am I? 8. Can I see where have I come from? 9. Can I see where am I going to? 10. Do the rooms help me see where I am going?

Table 6.3: Total Impact Assessment Toolbox: questions that assist visual task design.

Using this list should remind the designer that children do actually ask themselves and each other similar questions out aloud. The rhetorical method is often used in adult software manuals and interface design guides, especially the last three navigation questions. However, in the child's world, children react to these questions immediately and verbally in terms of the visual evidence on the screen. Children do not think in broad conceptual terms about the product. Talking out aloud to the screen may be a way of overcoming this significant difference between designers and users.

3: The manipulation task tool

The issues surrounding the benefits of children using the mouse to manipulate objects and so improving the quality of engagement and enhancing the learning experience were the focus of this summary in Table 6.4, '*me*' and '*I*' refers to the software user.

The manipulation task tool
1. How easy is it for me to move the...(object assigned to the mouse pointer i.e. beater/stick/grabbing hand) around? 2. What do I find out when I move the mouse? 3. What do I like about using the (tool – beater/stick/hand)? 4. What is it like making the mouse move things round the screen? 5. What are the different things I can do on the screen with the mouse?

Table 6.4: Total Impact Assessment Toolbox: questions that assist manipulation task design.

4: The classroom context tool

The classroom context tool in Table 6.5 communicates the issues discovered in the literature review regarding the positioning of the computer and screen which did not feature in the main study but are suggested to be an essential element embodying the new holistic paradigm.

The classroom context tool
1. Is the computer screen on the table (not on top of the CPU box)? 2. Is the viewer's eye above the top of the computer screen (when sitting down)? 3. Is the screen at arm's length away (average dark focus-v-natural resting distance)? 4. Is there room on the table for users to rest their lower arm when using the mouse? 5. Does the screen tilt away from the viewer (vertical screen causes visual stress – 50° tilt desirable)? 6. Are children briefed to understand these issues in the accompanying manual? 7. Is the computer screen on the table (not on top of the CPU box)? 8. Is the viewer's eye above the top of the computer screen (when sitting down)? 9. Is the screen at arm's length away (average dark focus-v-natural resting distance)? 10. Is there room on the table for users to rest their lower arm when using the mouse? 11. Does the screen tilt away from the viewer (vertical screen causes visual stress – 50° tilt desirable)? 12. Are children briefed to understand these issues in the accompanying manual?

Table 6.5: Total Impact Assessment Toolbox: questions that assist good ergonomic computer positioning in classrooms.

5: The teachers' control panel tool

The teachers' *control panel tool* in Table 6.6 concentrated attention on the features and quality of the control panel to help teachers organise the use of the software.

The teachers' control panel tool
1. What can I, the teacher, do with this control panel to organise my children's learning experience with a short classroom session? 2. Is the product capable of flexible organisation by me to facilitate progression and differentiation of learning? 3. Can I organise screen activities to make small changes in demands on children's educational development? 4. Can I present text at different levels of complexity for children with different abilities? 5. Can I control the audio element?

Table 6.6: Total Impact Assessment Toolbox: questions that assist the design of teacher's control of the software.

The 'Rules of Engagement' checklist

In addition, as a reminder of the quality of engagement theme in the thesis, the researcher proposed a set of Rules of Engagement in Table 6.7 be used as a final checklist – a *note* metaphor glued inside the lid of the *toolbox*. It was suggested that the checklist be actually pinned up on the wall above the computer screens of the design team. It was a quick reference list for educational software designers.

The 'Rules of Engagement' Checklist **(Put yourself in a child's shoes and ask what are you asking them to do…?)**	
1. Do I know what to do? 2. Do I know how to do it? 3. Does my computer tell me what to do if I make a mistake? 4. Can I find my way round? 5. Is it fun (*an enjoyable and absorbing activity*)? 6. Am I losing a sense of time (*through movement in concentrated activity*)?	7. Are the mouse movements easy for my small hands? 8. Does this screen let me do slightly different things easily? 9. Does this screen do different things that all add up to an enjoyable task? 10. Can I finish this task by break time?

Table 6.7: Total Impact Assessment Toolbox: a quick reference checklist for educational software designers.

6.2 The contribution from the literature review and main study

In this section the contribution from the evidence in the literature review to *the total impact assessment toolbox* is summarised.

The *teachers' control panel tool* was informed by the critical analysis of IT and ICT development in schools in the 1980s and 1990s which has revealed: the influence of the National Curriculum in information technology, the limitations of educational schemes that introduced 'hardware first' into schools, the inadequate staff development and consideration of classroom practicalities, the poor quality research into IT particularly in the early part of the period studied. In general, the result was to confirm the need to pay close attention to the reality of the classroom environment and of classroom practicalities. In particular this was achieved by incorporating a well-organised structure and a control panel interface in the research tool allowing teachers to manage learning experiences effectively. The *teachers' control panel tool* in the *toolbox* was used to assess this aspect of good design.

The evidence from both the literature review and the Research Tool used in *the total impact assessment toolbox* is summarised in Table 6.8 to indicate the overall approach to improving the quality of computer interface interaction for young children.

The ten features of the Research Tool	**The areas of study in the literature review**
Currently accepted standards with improvements	
1) Clearly defined tasks, *but* take advantage of vision issues.	**3.3.2 Children's eye function, field of view and vision issues.**
2) An easy to use interface, *but* in a child/computer configuration that resolves ergonomics controversies of desk angle.	**3.3.4 The role of ergonomics and human factors.**
3) Clear feedback from interface actions, *but* actions should have a physical/ manipulation component so feedback involves a wider range of senses.	**3.3.2 Children's eye function, field of view and vision issues:** Focussing of visual attention, eye movement related to thought and physical experience. **3.3.3 Conventional education theory:** The significance of manipulating objects in the learning process.
4) Easy navigation *but* take into account advantages of downward perspective viewpoint.	**3.3.5 Interface metaphors:** The potential role of improving learning using a downward perspective viewpoint.

Higher specification arising from the literature review	
5) The value of enjoyable and absorbing educational activities is formally recognised.	**3.3.2 Flow theory:** Interfaces which combine enjoyment with activity and a deeper form of engagement.
6) Interface activity through manipulation of screen objects that engages users in more concentrated activity.	**3.3.2 Flow theory:** Pleasure in using one's body. **3.3.4 The role of ergonomics and human factors:** manipulation – 'giving the qualitative feeling that one is directly engaged with the control of objects'.
7) Child friendly computer desks and mouse activities easily achieved by a small child's hand.	**3.3.2 Government initiatives:** Negative effect of the commercial 'hardware-first' approach. **3.3.2 Children's eye function, field of view and vision issues:** Computer screen configurations not optimised.
8) Interface activities that make small changes in demands on the user.	**3.3.2 Flow theory:** Environments that vary in difficulty increase both challenge and potential for learning.
9) Activities should have elements of multi-functionality to be absorbing without causing confusion.	**3.3.2 Flow theory:** Varying levels of difficulty enhances concentration and enjoyment.
10) A teachers' control panel to manage the organization of children's use of the software.	**3.2 IT in primary education:** Teachers need training in IT across all subjects in their classrooms.

Table 6.8: A summary of the relationship between the features in the Research Tool and areas of study in the literature review.

6.4 Summary

The *total impact assessment toolbox* incorporated the conventional planning methods of educational product design but with a new coherence and in a child-centred style. Combining together intellectual tasks, visual tasks and motor tasks, the *toolbox* encourages designers to reflect the holistic relationship of children and their computers. Enjoyment and pleasure are integral and justified features. The *toolbox* allows the combination of these factors to have an allotted organised place. It is possible that these factors may be most effective when the optimum screen configurations can be achieved. The *toolbox* is proposed as a formal method for improving children's multimedia products using appropriate, informal language for the age group. Just as in successful traditional media – TV and radio programmes, books and magazine articles – start from ideas 'written on the back of an envelope' because the production team understood the process, so these guidelines distil the features that promote success in new media. Success includes learning through a greater depth of engagement. The next chapter is a discussion of the research results, as well as suggestions for further study.

Chapter 7: Discussion, implications and conclusion

7.1 Introduction

Chapter 7 is a summary of the thesis, a discussion of issues emerging from the evidence, and implications for future practice and further research into improvements in the quality of interactive multimedia for young children. The first section of the chapter begins with a summary of the thesis, which makes a contribution to the knowledge of the subject and draws attention to three aspects that make the study of special interest to others involved in the field of interactive multimedia for young children. The second section of the chapter identifies the several ways the holistic paradigm can make a new contribution to the knowledge of the subject. The final section makes suggestions for improving the quality of interaction and interface design that could not be encompassed within the thesis.

7.2 Improving the quality of educational software design

The paradigm alerts practitioners to a range of coherent physical and physiological relationships between children and computers that work together to enhance features that deepen the quality of engagement including: an open-ended beginning to the software, inspiring audio instructions, enjoyment and pleasure, increasing complexity, and discussion. In addition, the paradigm contributes to a particular understanding of the educational value of the mouse as a tool for manipulation of object. The revised holistic view also provides a deeper understanding of the human-machine paradigm than conventionally held by ergonomists and HCI specialists. Coherence is provided by the experiential metaphorical concept *container* with its physiological aspects.

There are three general areas of the thesis that will be of special interest to others involved in the field of study:

1. The researcher can reasonably claim that as far as he knows from and extensive literature research there is no other thesis concerning the subject of transferring educational radio resources to a multimedia format.
2. The Research Tool in the thesis uses the technique of manipulation of objects as a key central feature of a software product, unlike many products that use the technique as one small, even 'gimmicky' element.

3. The thesis has children and computers as its central focus and has not assumed to apply accepted general ergonomic principles based on adult work environments.

Particular attention is drawn to the third element: a reassessed holistic paradigm facilitates improvements in the quality of computer interface interaction because the multimedia design process is now focussed firmly on the clients– children. *The total impact assessment toolbox* provides a set of guidelines helping practitioners identify the client's own level of possible interactions with the computer.

In the next section several aspects of methods to improve the quality of interaction are described in detail prefaced by comments from the point of view of the original sponsors of the study, the BBC.

7.2.1 Education radio resources for multimedia

The research began five years before the current trends in the British Broadcasting Corporation to create educational radio resources on the Internet, and at a time when the only other activity was focussed on creating CD-ROMs using television, video and publication assets. There are three specific areas in which the advantages of using radio resources for multimedia are justifiable:

1. The original educational aims of radio programmes can be retained and given added value. For example, the structure of radio programme ideas and content created by the original education team and manifested in the teachers' notes have been shown in the research to be transferable as a design brief for the new medium of multimedia.

2. The process of deconstructing a continuous linear radio programme has been demonstrated to be achievable. The results retain an effective structure despite the segmented multimedia educational experience. Physical follow-up activities, existing as ideas described in the radio notes can be replicated as real learning events involving physical manipulation on the computer.

3. The traditional educational radio values for children are retained and can be given added value in the new medium. Existing audio-triggered inspirational, motivating, creative stimuli become, for example, activities involving repetition, independent of teachers and the constraints of classroom organisation.

4. The opportunities presented by the DVD-ROM technology developed since the research was carried out provide a greater opportunity to include more audio, visual and video educational broadcast resources. The conclusions in this thesis are still valid in the light of changes since the study ended and continue to be so in the expectation of further developments such as the Internet.

7.2.2 A new approach to the manipulation of information

The paradigm proposal here applies the technique of manipulation in the context of educational program software as an integral part of the learning process. In the Research Tool the mouse becomes the beater of percussion instruments, it also becomes the hand putting stars into pockets. Children manipulate toys, books, clothes, and musical instruments. They talk and learn as they do so as described by Piaget (1952) (*see chapter 3 p. 96*). It should therefore have been no surprise that the mouse-as-multi-functional-tool involves children in talking to the computer and discussion between each other. The research has not studied the forms of discussion in detail, but discussion was demonstrated to be part of a greater degree of engagement with the computer. However, the thesis does demonstrate that multimedia design tools can be made to manipulate interface elements as a valid method of improving acquisition of information. The evidence provided by Piaget (1952) (*see chapter 3, p. 97*) and Vygotsky (1962) (*see chapter 3, p. 97*) pointed to the value of manipulation in the educational learning process in the real world. When manipulation is capable of replication in pseudo 3-D or virtual environments then the paradigm may result in further improvements in the quality of interaction.

The advantages of manipulation in conjunction with pleasure and attention to tasks that enhance learning have been demonstrated in the main study. Pleasure and attention are applicable not just to music, but any curriculum subject. Manipulating information using the computer mouse in combination with recognition of visual search theory make the paradigm especially meaningful to media practitioners. For example, consider users who might be exploring a product or location by clicking on an element on the screen with the result that suddenly the product image disappears and another separate page appears too quickly to notice. The paradigm could help design interfaces that engage users more effectively by using the method of an overlay or pop-up information panel, and ensuring the panel is placed within the narrow visual field where attention is focussed around the mouse pointer.

7.2.3 A new approach to audio instructions

The use of audio for instructions, for feedback, for clarification, for inspiration, for sheer pleasure and general enhancing of the quality and speed of learning has been explored in the Research Tool. The researcher's experience as a radio producer has led to special attention being applied to the use of audio, which may otherwise be given less significance in products that originated from individuals working in a conventional publishing, TV or design-orientated background. The value of teachers' easy control of the use of audio and its volume is also a necessary requirement of good design.

Most significant for good educational multimedia practitioners, the research suggested that the educational value of the software activities can be enhanced by the '*sequenced construction of audio instructions*' discovered from testing Activity 6 in chapter 5 *(see p. 153)*. The success of the sequence has further implications. Not only do the audio instructions for Activity 6 suggest that students can follow traditional didactic audio instructions independent of mediation by teachers in a multimedia product, but also audio instructions with future interactive and manipulation designs suggest opportunities for deeper learning experiences as yet undefined. For example, hidden elements ready for discovery, and its method of using pleasure, revelation and success in a structured way for children, under the control of teachers.

7.2.4 Eye and visual search theory

There are several implications arising from the study of the eye and visual search aspects of the thesis. The research found that looking down on a screen had two advantages. In physiological terms looked down was more effective for faster acquisition of information – up to 4% faster than the same information presented in the vertical plane. In addition looking down was also the preferred natural emotional state for reflective, safe, concentrated activity of reading and writing referred to, amongst others, by NCET (Bowell et al., 1994). Furthermore, the admitted compromise of the early keyboard-desk-TV screen standards by ergonomists suggests there was an unresolved design issue that deserves review.

Second, the research found there was an increase in speed of recognition resulting from the use of 3-D objects on a screen (Grossberg et al., 1994). The findings supported the view that these objects, if viewed from a vertical oblique angle were also easier to identify, which was a cause of the increased speed of recognition times.

The context of three children using a computer at one time – the common practice in primary schools – needs review. In a group of three, a central child in the group will have advantages of speed of recognition. Children on the periphery have to contend with distortion, and in the case of flat screens, a very limited angle of view in the horizontal plane because the intensity change is greater than tube screens.

7.2.5 Pleasure in learning and educational simulations

The holistic paradigm creates an authoritative framework not only for recognising the value of pseudo 3-D perspective interfaces but also simulated learning environments by showing the educational value in concentrated activity that gives users pleasure. Many of the activities in the Research Tool were open-ended, as in many simulations. The activities were open to children making a sequence of further discoveries, another feature of simulations, through repetition and refocusing under the guidance of a teacher.

The activities did not have the didactic structure of contemporary CD-ROMs favoured by many educationalists. The potential for sophisticated CD-ROM simulations in educational software appears to have had its source in United States imports of commercial edutainment material into UK schools.

The value of educational simulations is most frequently justified by educationalists because the activity involves children in problem solving, gathering information, and planning strategies (McFarlane, 1997). The qualities in an edutainment adventure game that create engagement were difficult to analyse. The educational acceptance of an interface that has planned hidden features not immediately revealed was very much against conventions. But the need of discovering and understanding the whole picture was at the core of a dialectical, reiterative educational process that was known to be good traditional teaching. Discovery and revelation are the exciting and enjoyable features of learning. The same elements of discovery are some of the exciting and enjoyable features of good shoot 'em up games software! However, harnessing these elements and using it to educational advantage, structured and managed has coherence through the new paradigm and *the total impact assessment toolbox.*

The new paradigm may help those teachers who see the clear educational value in simulations, yet do not understand why they worked. It is hoped that in providing a model that allows the incorporation of flow theory, the paradigm will stimulate a revival of adventure games and simulations and advance the genre.

7.2.6 Metaphors – the physical component

The value of redefining the meaning of metaphor as currently applied to new media is, the researcher proposes, a useful contribution of the thesis. Informed by Lakoff and Johnson (1980), the thesis attempted to understand why interface metaphors may continue to operate less efficiently than interface designers intended. The reason, it was suggested, was the tendency for metaphor to be applied by interface designers in a superficial rather than the deeper, comprehensible way in the new paradigm where more emphasis was placed on user's ontological and interactional experience of computers.

7.2.7 Teachers' control of software

At the time when the Research Tool was originally designed there were few CD-ROM media with a teachers' control panel built into the design. Those that did chiefly employed the technique of users choosing their own level of ability and skills at the outset. The principles of guiding and recording learning have always been a core theme of CAL software too. At the time, the general view was that multimedia products could operate without teacher mediation, and even took away their responsibility for enabling learning. The criticism of educational CD-ROMs was that they were full of a great deal of unorganised information, too much for teachers to discover. Arranging information to meet an individual teacher's needs for differentiation and progression in the classroom within a realistic daily work schedule was not addressed. The claim of the thesis is that the teachers' control panel in the Research Tool was a coherent, integral and hidden element for everyday use in a busy classroom, which gave teachers full control over all aspects of the teaching content.

7.3 Future directions for improving the quality of interaction

In the penultimate part of this summary chapter of the thesis are suggestions and implications for further developments and research into ways of improving the quality of interface design that could not be encompassed within the thesis.

7.3.1 Applications for the container metaphor

The implications for the use of the *container* metaphor have drawn on evidence of not just the metaphorical and physiological aspects, but the powerful operation of the two in combination (*see chapter 3, p. 105*). However, the advantages of more effective acquisition information in a pseudo 3-D perspective interface could not be widely applied in the Research Tool because of commercial constraints in the development schedule.

Whilst the advantages in the new paradigm of the experiential metaphorical concept, *container* have been proposed and applied partially in the story interface of Research Tool interfaces, a higher level of 3-D navigable interface remains an educational goal worth achieving. This goal has had to be left to others to complete, with software becoming available since the research began such as Director 8.5, which has a built-in 3-D library, and the easy-to-use and cheap Flash software.

7.3.2 Software ergonomics

The significance of screen orientation and screen position on the desk, which reflects the fundamental requirements of eye physiology, could not be fully explored in the research, but the implications were encompassed in *the classroom context tool* of '*the total impact assessment toolbox*'. Further study in a classroom is required in the context of the use of personal computer screens investigating the relationship between upright and sloping screens and the speed at which data is accessed. The results might lead to a greater understanding of user comfort, attention span and reduction of stress in the classroom.

7.3.3 QuickTime VR in an education environment

The recent development of QuickTime VR could not have been foreseen. Indeed it had not been commercially available when the thesis began. Its origins came from sources other than visual search (essentially software experts exploring algorithms that result in images being compared and 'stitched' together seamlessly). However, the experiential metaphorical *container* described in the new holistic paradigm seems to be already widely available in QuickTime VR. Indeed, though it is a 'rough and ready', relatively low technology in relation to immersive virtual reality methods, the *container* metaphor functions in its spherical distortion of space imitating the human eye before the brain 'sees', as a more effective method of navigation. Pixel-based virtual reality photography is being applied in many websites and for educational purposes. QuickTime VR may have educational value to children without waiting for fully immersive virtual reality technology to arrive.

7.4 Implications for further research

In the final part of this thesis summary are suggestions and implications for further research into the interrelationship between children and computers arising from the new holistic paradigm.

7.4.1 Education software design

Eye and visual search theory

There are no references in the marketing information for flat computer screens of their real advantages expressed in terms of the discoveries made in this research. The implications for manufacturers of flat screens are relevant, as they currently appear to be only concerned with selling the technology itself, as well as the space advantage it provides, in contrast to conventional cathode ray tube screens.

Laptops are now in general use and have more flexibility to be used at different vertical angle of view. Which vertical viewing angle is preferred? If users were aware of the value of options would they change their habits? Is the screen angle determined by convention or by visual clarity of current LCD panel design? The advantages described in this research of tilting the screens to around 40° to 50° from the horizontal have yet to be explored fully. Current government sponsored research is focussed on advantages of laptops from factors such as flexibility of room use and advantages of wireless connectivity 'we were impressed with the potential of laptops with wireless connectivity to enrich teaching and learning' (Sawtry Community College, 2002). Further research into the ergonomic aspects for example the potential for creating screens that can be used in a variety of positions should be carried out.

Observations about screen tilt have special research applications to the recent huge growth in internet use too. Are there research opportunities for establishing whether designers of website pages really should avoid the presence of text and pictures hidden below the field of view of users in the page? Is it, as evidence in other contexts suggests, because the hidden element below the line of sight creates an instinctive anxiety related to the absence of lower body awareness?

It may even be possible to develop a simple test using a metre ruler for children to identify their own preferred angle of view and dark vergence point and adjust their own screen accordingly (especially with the introduction of laptops). A general raising of awareness of visual fatigue and difficulty in fixating would also inform ICT providers in the school environment.

Manufacturers might find evidence in the thesis significant enough to encourage research into future developments for detachable screens, which can be used both on the lap and written on, and also tilted near vertical for other kinds of tasks. At least users should have the flexibility to reposition the screen to suit mood, temperament and perhaps certain specialised tasks. Further precision into user requirements might be revealed by more research exploring the new paradigm provided by a tilted screen with different orientations for different tasks.

What are the ergonomic effects of users continually using the mouse for scrolling down to reveal the hidden element? Is the browser environment exhausting users? Also a menu on the left-hand side of the screen with tiring mouse moves to a right-hand side-scrolling bar might be unacceptable in the future.

Metaphors – the physical component

The thesis has considered Lakoff and Johnson's work (1980), and placed it in a context unexplored by the authors themselves – educational environments. The *container* metaphor might be applied not just to children and computers, as in this thesis, but to the education environment generally and the classroom in particular. The classroom as a *container* may require teachers to re-synthesise their separated academic and physical experience of the world. However, advantage for the education community is the potential for reassessing and redefining the features of good teaching in terms of a dynamic, 3-D learning process. For example, by applying the *container* principles to generic educational tasks so including physical activity to help children understand concepts, the description and operation of technical devices, and visualising ideas. The groundwork for the way forward in both these respects is proposed in this thesis.

A new approach to the manipulation of information

Future research in the area of manipulation of information should be carried out into testing recognition times for various tasks at different angles of screen tilt, not just writing and hunting for information, but also carrying out manipulating tasks. There may also be a case for testing flat screens which users can write on directly (only currently available for high-end graphics systems) and which could be of value to children in an educational environment. Manufacturers may find support in this research for promoting the greater use of this kind of screen in schools that should be included in development programs.

A new approach to audio instructions

Further testing to explore the apparent attractiveness of Activity 6 of the Research Tool could be of interest to researchers. The focus might be the replication and development of didactic teacher instructions recreated using the recent techniques in multimedia software programming. Researchers might refine the sequence and provide children with the controls to activate the elements more effectively now programmers are more experienced and functions are more advanced.

The educational value of audio is shown in the results of the research. Even though the trials in the research have been on a CD-ROM product, the findings can be equally applied to web-based children's audio activities, especially through Java applets. The principal direction will be to enhance the accessibility of text-based website pages for younger children by the extensive and specialised use of audio. The visual element might be improved with audio repetition, audio revelation responses and feedback, audio associated with manipulation and the *'sequenced constructions of audio information' (see chapter 5, p. 153).*

Pleasure in learning and educational simulations

The *total impact assessment toolbox* could be used to aid the design of simulations, enshrining principles that do not involve the high cost of developing commercial gaming software. These principles can be used to incorporate essential features. The process will allow educationalists to have an informed input to an interactive gaming design team. Research is called for to re-evaluate the use of simulations within an educational environment.

Teacher organisation of software

Developers of CD-ROMs might consider further research into providing teachers' control panels used in the Research Tool to enable the more effective use of the vast quantity of resources on one CD-ROM disc. The efficacy of revising existing assets by adding teachers' control panels that provide structure to learning is possible while maintaining the pleasure and fun of the learning experience. The use of a teachers' control panel to manage presentation of material on a CD-ROM, manifest in a practical manner the educational value of putting teachers and their need to structure computer use first in the classroom environment. It may be a valuable method to use to inform the use of teachers' controls for web-based learning too.

7.4.2 Interactivity and the Internet

The research in the thesis points to some important implications for current educational developments of the Internet, and in particular for website interactivity. During the period of the research, attention has shifted from educational CD-ROM multimedia products to the educational potential of the Internet. The thesis has demonstrated the potential educational advantages of turning a radio programme into an interactive CD-ROM. The research suggested that taking a step further and creating an interactive radio product using Internet technology may also have similar advantages.

Educational radio is, in fact, a great potential asset for the Internet for the following reasons:

1. Developments in streaming audio, advances in server technology and the future potential of broadband delivery methods.

2. The slide tape or Radiovision products that were such a feature of the BBC Education Department in the 1970s were a powerful and unique educational experience defined by the technology of the time. They had an impact on children's visual experience of large-scale searchable still images enhanced by an audio picture. Now, using the current Internet technology, children can have the advantages of the Radiovision experience, but with the added value of a close-up, focussed, audio-visual experience delivered when children want it, not confined by past problems of a blackout, dim slide projector and indistinct tape recorder.

3. The evidence of navigable structures in a radio script and the role of textual coherence provided in the thesis inform those working on the Internet, where navigation is a key issue.

4. Developments in Internet software will make visually three-dimensional (3-D) interactive navigable radio programmes on the Internet a possibility. The ability to use enhanced manipulation techniques in the Internet environment is currently more complex, though Java-based applets and software such as VRML, SuperScape and QuickTimeVR are increasingly allowing the use of a mouse as a tool for manipulation and immersive experiences.

5. The ideas of a teachers' control panel explored in the CD-ROM Research Tool could be achieved in the Internet environment with little practical technical difficulty. Planners of future projects may find the results in this area of the thesis of value when exploring the potential in their own website design.

6. Finally, though not directly proven by the research, the evidence points to general environmental problems that children might experience in the classroom arising because of the relatively crude features of current HTML design used in, for example, educational websites such as:
    a. Visual strain problems arising from scrolling down pages to find hidden elements.
    b. Ergonomic factors relating to continual scrolling and clicking on menus in visually or physically uncomfortable places around the computer screen.
    c. The application of the *navigation* metaphor, shown in the research to be flawed in many respects is almost universally used on Internet page design. The implications of the role of the *container* metaphor and the need to involve users in a three dimensional metaphor have been identified in the research.
    d. Manipulation as a technique on the Internet is still in its infancy. The technique exists but the examples of applications appear to be limited as yet. The conclusions from the Main Study *(see chapter 5 criteria 1, p. 174 and 6, p. 185)* suggested manipulation methods already available in Java and other new scripting methods could be applied in a constructive manner to the advantage of educational products.

7.5 Implications for future research methodology

The thesis can claim to have employed new technical methods of conducting research that were not in use at the time the main study was carried out. This section summarises the advantages which others may like to employ in their own work.

7.5.1 The digital audio recorder

Researchers who have had to carry out or supervise the lengthy, time-consuming and exhausting research using conventional tape recorder and typed transcripts will recognise from the descriptions in the methodology chapter just what advantages the new technology used in the thesis can provide. It has been shown how the technical needs for the ability of recording for long periods, unobtrusively and confidently, with clarity of signal and without interference from the computer have been met. The ability to search, collate and transcribe far more accurately and efficiently allowing for more time spent on the analysis of the content should also be self-evident. The methodology demonstrated the value to future researchers of a systematic approach using the new technology and pointed to benefits in other research contexts.

7.5.2 The digital database

The advantages of the digital recorder were fully realised in conjunction with the computer database software (FileMaker). The principle of using a database itself might not be new. What is a new development is the technique of being able to turn a generic database product quickly and easily to support manual data analysis, specific to the task. A second feature is being able to load the digitally transcribed information into the searchable electronic file cards quickly, accurately and effectively. The research shows that problems such as quality of sound, battery duration, and transcription using conventional tape recorders as observation tools may have been successfully overcome. It is suggested that advice against the use of tape recorders in current research methodology textbooks should be reviewed to include the use of digital recording methods.

7.6 Conclusion

What are the design features required to improve the quality of computer interface interaction for 5 to 7-year-old children?

The research question has revealed a complex set of factors that challenges assumptions of the early screen designers, and proposes a new paradigm that accounts for the design features that improve the quality of interaction. Attention is focussed on new directions for Internet development.

The process of the research has been one of reviewing, reconstructing and testing factors that influence effective interface design for children, of redefining known elements and of introducing new ones in a coherent strategy for a greater depth of engagement through a new holistic paradigm of child and computer. Ergonomists knew of the unresolved controversies in their analysis of the human-computer relationships they designed. Now, technology has provided new opportunities to solve the inconsistencies.

The contribution of the thesis is to inform design ideas emerging with the new media technologies. Educational ICT practitioners have a reference in the thesis to inform opportunities for child-centred developments with deeper engagement and a fuller learning experience.

The researcher intends that those interested in education will consider the proposals in this thesis for improving the quality of interface interaction, a useful contribution, and apply them to their own computer media to achieve and maintain high standards in education.

Glossary of terms

Analogy Similarity: Expression or an expression involving explicit or implied comparison of things basically unlike but with some striking similarities (Merriam Websters's Collegiate Thesaurus).

Archimedes A computer mainly used in schools produced by Acorn Computers. For the six months ending in June 1997 Acorn's turnover dropped by £2.3m to £14.2m. Acorn Computers Ltd was purchased on Tuesday 1st June 1999 by Morgan Stanley Dean Witter.

AUCE Advisory Unit Computers in Education. The Advisory Unit is an independent organisation offering IT services and educational software to schools.

BBC Micro An early personal computer developed principally for schools by the BBC. The BBC Micro was launched to coincide with a computer literacy drive by the BBC. The machine had possibly one of the best versions of BASIC out of all of the computers at the time and also had good expansion capabilities including networking.

BECTa British Education Communications and Technology Agency formerly the National Council for Educational Technology.

CD-ROM An abbreviation of Compact Disc ROM (Read Only Memory). Data is written in 2048 byte blocks. Data held in pits and grooves on the disc and read by a laser beam.

Cognitive psychology
The study of human memory, learning, knowledge presentation and skill acquisition.

Edutainment A term to describe early CD-ROM titles (US) which were considered to be of educational value at home as well as school presenting educational material in an entertaining manner. Also meaning a product which failed to achieve either objectives.

Engagement Attract attention, employ occupy (person, powers, thought). Emotional involvement or commitment (Oxford Illustrated Dictionary).

GUI An acronym for graphical user interface.

HCI Human-computer interaction is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena in the interactive relationship.

ILS Integrated Learning System. A computer program that provides interactive learning resources which track student's progress, gives feedback of sections completed, marks attained for tests and records student's data for analysis by a supervisor.

Isomorphism
The creation of possibilities of individuals learning from other systems. Isomorphism is demonstrated in NLP therapeutic situations when individuals are encouraged to connect the stories they tell about events in their lives to their behaviour.

IT Information Technology or Informatics can be defined as the science of processing information by machine. This is a narrow definition, but includes the following elements, which define the variety of IT applications in Primary Schools over the years. These are programming, Computer-Assisted Learning, Simulations, Multimedia Software and Information Retrieval. IT is also considered to be synonymous with basic IT skills.

ICT Information and Communications Technology, "something that supports education goals". Broad categories of the applications of ICT used in education include:

1. General tools, applied for specific uses in education, e.g. word processing, presentation, spreadsheet
2. Communications software; e-mail, video conferencing, Internet browsers. resources, especially Internet/Web based, whether of a general or specific educational nature.
3. Computer-assisted instruction e.g. drill and practice, integrated learning systems (ILS). These are 'systems across computer networks that deliver computer-assisted instruction, and which record and report student achievement'.
4. Computer-based assessment tools, still in early development. Examination boards are working on computer-based examinations.
5. Management tools; classroom procedures, students' progress, deficiency analysis etc financial, personnel and educational resources; presentation of results externally to parents, governors, inspectorate, general public; communication with parents and students.

Interactive Of, relating to, or being a two-way electronic communication system (as a telephone, cable television, or a computer) that involves a user's orders (as for information or merchandise) or responses (as to a poll) (Merriam-Webster's Collegiate Dictionary)

Internet A world-wide computer network, which is formed from many local area networks (LANs). It has no central point and uses whatever network connections it can find to transmit its own data packets.

JMI Junior, Mixed and Infants School, a common form of primary school organisation with an infants departments and with children staying on until 11 before going to Secondary school instead of moving to a Middle school first.

Manipulation

To treat or operate with the hands or by mechanical means especially in a skilful manner (Merriam-Webster's Collegiate Dictionary).

Mouseup/Mousedown

Occurs when the user presses any mouse button. Often used with the corresponding MouseDown event to define what occurs when a mouse button is pressed and released.

Metaphor "A figure of speech by which a thing is spoken of as being that which it only resembles, as when a ferocious man is called a tiger" (Chambers' Twentieth Century Dictionary).

"A figure of speech in which a term is transferred from the object it ordinarily designates to an object it may designate only by implicit comparison or analogy, as in the phrase 'evening of life.'" (American Heritage Dictionary).

Metonym 'Metonymy is the evocation of the whole by a connection. It consists in using for the name of a thing or a relationship an attribute, a suggested sense, or something closely related, such as effect for cause the imputed relationship being that of contiguity' Wilden, Anthony (1987): The Rules Are No Game: The Strategy of Communication. London: Routledge & Kegan Paul

Multimedia The use of computers to present text, graphics, video, animation, and sound in an integrated way. Long touted as the future revolution in computing, multimedia applications were, until the mid-90s, uncommon due to the expensive hardware required. With increases in performance and decreases in price, however, multimedia is now commonplace. Nearly all PCs are capable of displaying video, though the resolution available depends on the power of the computer's video adapter and CPU. (Webopedia.com Internet dictionary definition).

NCET National Council for Educational Technology.

New Media There are two fundamental points that distinguish "new" media from media that preceded it, much of which still exists:

1. how it is transmitted and accessible ‹ both the new emphasis on the integration of text, pictures, video, sound; and the increasing use of the internet as the vehicle;
2. interactivity — this is both a defining feature of "new" media and likely to be the most significant area for "future new" media development.

Encompassing, the integration of computers, computer networking, and multimedia.

(Canadian Radio-television and Telecommunications Commission)

Ontological The human concern for physical orientations, objects, substances and seeing.

PDF Portable Document Format. Adobe software which ensures that documents in PDF preserve the exact look and content of the originals, complete with fonts and graphics, and can be printed, distributed by e-mail, and shared and stored on the Web, an intranet, a file system, or a CD-ROM for other users to view on all platforms.

Radiovision A term used to describe a filmstrip sent to schools with an audio accompanying broadcast on national radio. The system was developed by BBC School Radio. The practice has now ceased and a complete archive of the output is available at the Institute of Education, London.

Shareware Software that can be used for a nominal fee to the author.

Starcatcher The title of a series of music programmes broadcast for 5 to 7 year old children under the Time and Tune School Radio Series.

Usability Engineering

A study of the effectiveness, efficiency and satisfaction with which specified users can achieve specified goals in particular environments.

VDU Visual Display Unit. An early name for a computer screen.

WWW The World Wide Web is a collection of documents with web pages that can contain text, pictures, audio and video and other elements like virtual reality. The World Wide Consortium has taken on the responsibility for evolving the various international protocols and standards associated with the Web. It is an international industry-supported consortium, jointly hosted by three institutions:

the Massachusetts Institute of Technology's Laboratory for Computer Science -- MIT/LCS (America); the National Institute for Research in Computer Science and Control -- INRIA (Europe); and Keio University Shonan Fujisawa Campus (Asia). All three hosts work together to form the "W3C Team", providing a neutral leadership in the evolution of the Web.

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Appendices

Appendix 1: Main study data collection schedules.

Appendix 2: British Journal of Educational Technology Paper, 'Visual Elements and container metaphors for multi-media'.

Appendix 3: List of papers and presentations during the research period.

Appendix 4: Starcatcher programme 1 of the series, (cassette tape) pupil's booklet and teacher's notes. *(See attached in separate folder.)*

Appendix 5: The CD-ROM of the Research Tool (Mac version). *(See attached.)*

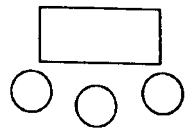
Appendix 6: Field Work Diary Part 2: Titles of the PowerPoint reports for BBC Education Directorate
(See in file Fieldworkdiary2.doc on accompanying CD-ROM for PowerPoint presentations)

Appendix 1:

Main study data collection schedules: showing school name, date and time, the focus of areas of interest and the seating plan of the children used to log names.

OBSERVATION SCHEDULE
School: **WOOD END**
Date:20 May 1997
Time:
Focus:

Child seating Plan



THE OPENING SCREEN
a) The design and screen layout b) The instructions c) The actions using the mouse

ACTIVITY 1
a) The design and screen layout b) The instructions c) The actions using the mouse

ACTIVITY 2
a) The design and screen layout b) The instructions c) The actions using the mouse

ACTIVITY 3
a) The design and screen layout b) The instructions c) The actions using the mouse

ACTIVITY 4
a) The design and screen layout b) The instructions c) The actions using the mouse

ACTIVITY 5
a) The design and screen layout b) The instructions c) The actions using the mouse

ACTIVITY 6
a) The design and screen layout b) The instructions c) The actions using the mouse

THE STORY
a) The design and screen layout b) The instructions c) The actions using the mouse

THE SONG
a) The design and screen layout b) The instructions c) The actions using the mouse

Children's interview schedule showing the name of the school, date, question checklist child name log, for audio recordings.

CH = Child

CH1	CH2	CH3	CH4	CH5

Wood End 20th May 1997
Children's Interview Schedule
A reminder
The focus of the study is
a) The design and screen layout
b) The instructions
c) The actions using the mouse

THE OPENING SCREEN
1) What did you do when you saw the opening picture?
2) When you saw the first picture what did you think about?
    PROMPT: Tell me more about it
    PROMPT: What happened after that
3) What did you think you had to do when you saw this screen?
4) What did you want to click on first?
5) Did you have any idea who Starcatcher might be?
6) Did ytou have any feelings when you saw the screen?

ACTIVITY 1
1) Was it clear what you had to do just from the pictures on the screen?
2) Did you understand what the children were telling you to do?
3) What did you find out when you moved the mouse around?

Supplementaries
4) Tell me what y ou were doing with the screen?
5) How easy was it to move the letters around?
6) What did you think about when you were moving the letters around?
7) What did it make you feel like?
8) What words would you use to tell me how you felt when you were moving the letters?

ACTIVITY 2
1) Was it clear what you had to do just from the pictures on the screen?
2) Did you understand what the children were telling you to do?
3) What did you find out when you moved the mouse around?

Supplementaries
4) What did you think was going to happen when you moved the planets?
5) What did you feel like when you put them in to the pockets?

ACTIVITY 3
1) Was it clear what you had to do just from the pictures on the screen?
2) Did you understand what the children were telling you to do?
3) What did you find out when you moved the mouse around?

Supplementaries
1) How different is it from the previous task?
2) How easy was it to do this task?
3) Do you like moving things around?
4) Did moving things around help you do what was asked?
5) What did you think about when you had to move the planets in to the pockets?
6) Why did you think you had to move the things about?
7) How would you have done this task without the computer?

Children's interview schedule con't

ACTIVITY 4

1) Was it clear what you had to do just from the pictures on the screen?
2) Did you understand what the children were telling you to do?
3) What did you find out when you moved the mouse around?

Supplementaries

4) What did you like about moving the beater?
5) Was this easy or difficult to do at first?
6) What was /easy/ difficult about it?
   Tell me about that?
6) How did moving the instruments help you?
7) What do you think was going to happen when you moved the instruments?
8) Why did you think you had to move the instruments?

ACTIVITY 5

1) Was it clear what you had to do just from the pictures on the screen?
2) Did you understand what the children were telling you to do?
3) What did you find out when you moved the mouse around?

Supplementaries

4) How is this different from the other (previous)
5) What did you think about this?
6) Is there something you don't like about this?
7) What did you like about this task?
8) Tell me what you feel about moving the stars around?

ACTIVITY 6

1) Was it clear what you had to do just from the pictures on the screen?
2) Did you understand what the children were telling you to do?
3) What did you find out when you moved the mouse around?

Supplementaries

4) What are all the different things you can do with this task?
5) Which do you like doing most?
6) What is best and worst about this task?

THE STORY

1) Was it clear what you had to do just from the pictures on the screen?
2) Did you understand what the children were telling you to do?
3) What did you find out when you moved the mouse around?

Supplementaries

4) What did you think was going to happen here?
5) Did you feel you were going to see her with the children?
6) What did you think about Starcatcher when you saw him?
7) Do you think he was nice or nasty?
8) What are the differences between this story and reading a book?
9) What does looking down on the picture make you feel like?
10) What does taking the children in to the house make you feel like?
11) Do you think you are going into the house with the children now ?
12) Is Starcatcher a real person?
13) Would you like to meet Starcatcher?
14) What would he say to you?
15) When you clicked and dragged the child into the house what did it make you feel?

CH1	CH2	CH3	CH4	CH5

Children's interview schedule con't

SONG
1) Was it clear what you had to do just from the pictures on the screen?
2) Did you understand what the children were telling you to do?
3) What did you find out when you moved the mouse around?

Supplementaries
4) How does it help you to learn songs?
5) What is the difference between learning a song like this and in class?

GENERAL QUESTIONS

1) Is there one word you could use to tell me about the software?

2) Can you tell me how this software is different from other computer software in the school??

3) What do think about the idea of listening to what to do?

4) What do you think about children's voices giving you things to do.

5) Tell me what it is like making the mouse moving things around the screen?

CH1	CH2	CH3	CH4	CH5

Teachers' interview schedule

Name:
School
Teaching Experience:
Specialism:

Preamble

The study is an in depth exploration of *"what features of the Starcatcher interface improve the quality of interaction"*.
The *interface* means the computer screen.
Interaction means how the children are involved or are engaged by the interface.
The focus of the study is not the subject matter which is music, but the interface itself.

I would like to ask you about several key features about the design of the Starcatcher interface that the authors consider important. I am particularly interested in how the interface works in practice.

You are asked to just observe what some of the children are doing on the computer during the day making sure you are able to see the progam in total during that time (max 15 mins).

GENERAL QUESTIONS

1. Is there one comment about the software that strikes you right away as the most important to make?
2. How do you think the way the software works compares to other multimedia products in the school?
3. The authors believe the voice instructions are a very important part of the interface because children don't have to read?
4. The authors believe it is important that the instructions are read out by children, because they provide peer group confidence?
5. The authors say children are more engaged in the learning process because children are using the mouse like at tool (beater) in this product.

Teachers' interview schedule con't

The questions focus on the quality of:

a) The design and screen layout

b) The instructions

c) The actions using the mouse and the role they each play in fully involving children in completing the task.

The research also seeks to make a comparison between the different interfaces.

PARTICULAR QUESTIONS ABOUT EACH INTERFACE

Discussion whilst looking at the interface

THE OPENING SCREEN

1. What comment have you to make about the instructions?
2. To what extent does the artwork clearly indicate the task to be done by the children?

PROBE: The authors say this interface works because an open question encourages children to explore?

PROBE: What do you think would happen if children were told what to do?

3. What would you like to say about this screen and how it works in the classroom?

SUMMARY: Were there particular comments to note from your observations of what the children did?

ACTIVITY 1

1. What comment have you to make about the instructions?
2. To what extent does the artwork clearly indicate the task to be done by the children?
3. The authors believe this interface helps children to spell because children have to move the letters around rather than type them in?

1. To what extent do you think that moving the letters around helps or hinders children in achieving this task?
2. What comments have you to make about the way children were using the mouse?

SUMMARY: Were there particular comments to note from your observations of what the children did?

Teachers' interview schedule con't

ACTIVITY 2

1. What comment have you to make about the instructions?
2. To what extent does the artwork clearly indicate the task to be done by the children?
3. To what extent do you think that moving the objects helps children in achieving this task?
4. To what extent do you think that moving the objects hinders children in achieving this task?
5. What comments have you to make about the way children were using the mouse?
6. How does this task differ from the previous task?

SUMMARY: Where there particular comments to note from your observations of what the children did?

ACTIVITY 3 to ACTIVITY 6

1. What comment have you to make about the instructions?
2. To what extent does the artwork clearly indicate the task to be done by the children?
3. What comments have you to make about the way children were using the mouse?
4. PROMPT: To what extent do you think that moving the objects helps or hinders children in achieving this task?
5. How does this task differ from the previous task?

SUMMARY: Were there particular comments to note from your observations of what the children did?

THE STORY

1. What comment have you to make about the instructions?
2. To what extent does the artwork clearly indicate the task to be done by the children?
3. The authors believe the story interface involves children more because they have to take themselves (click and drag) into the story?
4. The authors believe the story interface involves children more because of the looking down nature of the interface?
5. The authors believe the story interface involves children more because the interface allows them to look over the shoulder of the children in a story?

SUMMARY: Were there particular comments to note from your observations of what the children did?

THE SONG

1. What comment have you to make about the instructions?
2. To what extent does the artwork clearly indicate the task to be done by the children?
3. The authors believe the interface will help children to learn the words and the tune of songs more quickly?

CLARIFY: What effect has the ability of the screen to highlight words as they are sung?

CLARIFY What effect has the ability of children to repeat the words and the tune?

4. How would you use this element of the package in the classroom?
5. How might it change the way you taught the tune and the song

SUMMARY

Were there particular comments to note from your observations of what the children did?

TEACHER'S CONTROL SCREEN

Demonstration first:

1. Experts may say that because you, the teacher can switch sections on and off you are now in control of the software. Comment?
2. Would you find this screen easy to use yourself?
3. How would this screen help you organise classroom activities and learning?
4. The authors believe the control screen allows you to organise work for different ability levels in the class.

FINAL SUMMARY COMMENTS

1. What views do you have about this software?
2. Does the organisation of the software fit in with everyday classroom practice?
3. The authors say that because groups of three children are the most usual in a primary school the interface is ideal for group work.
4. Could you identify one aspect of the interface that works well?
5. Is there anything else you would like to add?

Appendix 2

British Journal of Educational Technology Paper, 'Visual Elements and container metaphors for multi-media'.

Copy of the original paper.

Appendix 3:

List of papers and presentations during the research period

Work in progress, Presentation, School of Cognitive and Computing Sciences, University of Sussex, June, 2000.

Implications of current (PhD) research for course design and content. 5th Annual Research Conference, West Herts College, July, 2000.

VR: the Educational advantage, VR and Business lecture programme for DTI TEC North Wales, November, 1999.

Demonstration of *VRprojects* software, The Metropolitan Police Forensic Science Laboratory (MPFSL), October, 1999.

Virtual Reality the commercial potential, Presentation, DTI VR Forum April, 1999.

Virtual Reality Photography: a new educational tool, paper, CAL 1999, Virtuality in Education. March, 1999.

Teaching Geography: *Virtual Reality Photography for Geographers*,.Vol 24, No:1 January, 1999.

Primary Geographer. *The Virtual Reality School Trip.* No: 33, April, 1998.

Aerial Virtual Reality Photography Paper, GIS Conference, Birkbeck College, May, 1998.

Virtually Helicopters, Article, Virtual Reality Helicopter Rotor Torque Autumn, 1998.

Virtual Photography for Geography, Presentation, Geographical Association Conference, April, 1998.

Visual elements and container metaphors in multimedia, British Journal of Educational Technology. Vol 28, No: 2 April, 1997.

Types of Learning with IT, Course, School of Education Licensed Teachers, June, 1997.

Work in progess, presentation, MENO (Multimedia and Narrative Organisation): Workshop for Designers, Institute of Educational Technology, Open University, November, 1997.

The Virtual University, presentation. Middlesex University School of Education Staff Awayday, January, 1997.

Don't get lost navigating Multimedia: - use the container metaphor. paper, Mucort: Middlesex University Research Conference Dec, 1996.

What Makes Children Click? Paper Leicester University School of Education, October, 1996.

Strcatcher Project Update, presentation, BBC Radio Venture Centre. March, 1996

Research update Paper, School of Education Middlesex University. January, 1996.

Starcatcher Interactive , BBC Education goes Interactive, accepted 'Euro Education 96' Denmark.

Work in progress, Paper Research Seminar Middlesex University School of Education March, 1995.

Work in progress, Presentation. Human Factors Dept. British Aerospace. Sowerby. January, 1995.

What makes children click? Keynote speaker at International Conference of Media Communications, MediaCOM, 1995.

Mapping Childhood metaphors in 3-D, WCCE, paper World Conference in Computer Education, Birmingham, July, 1995.

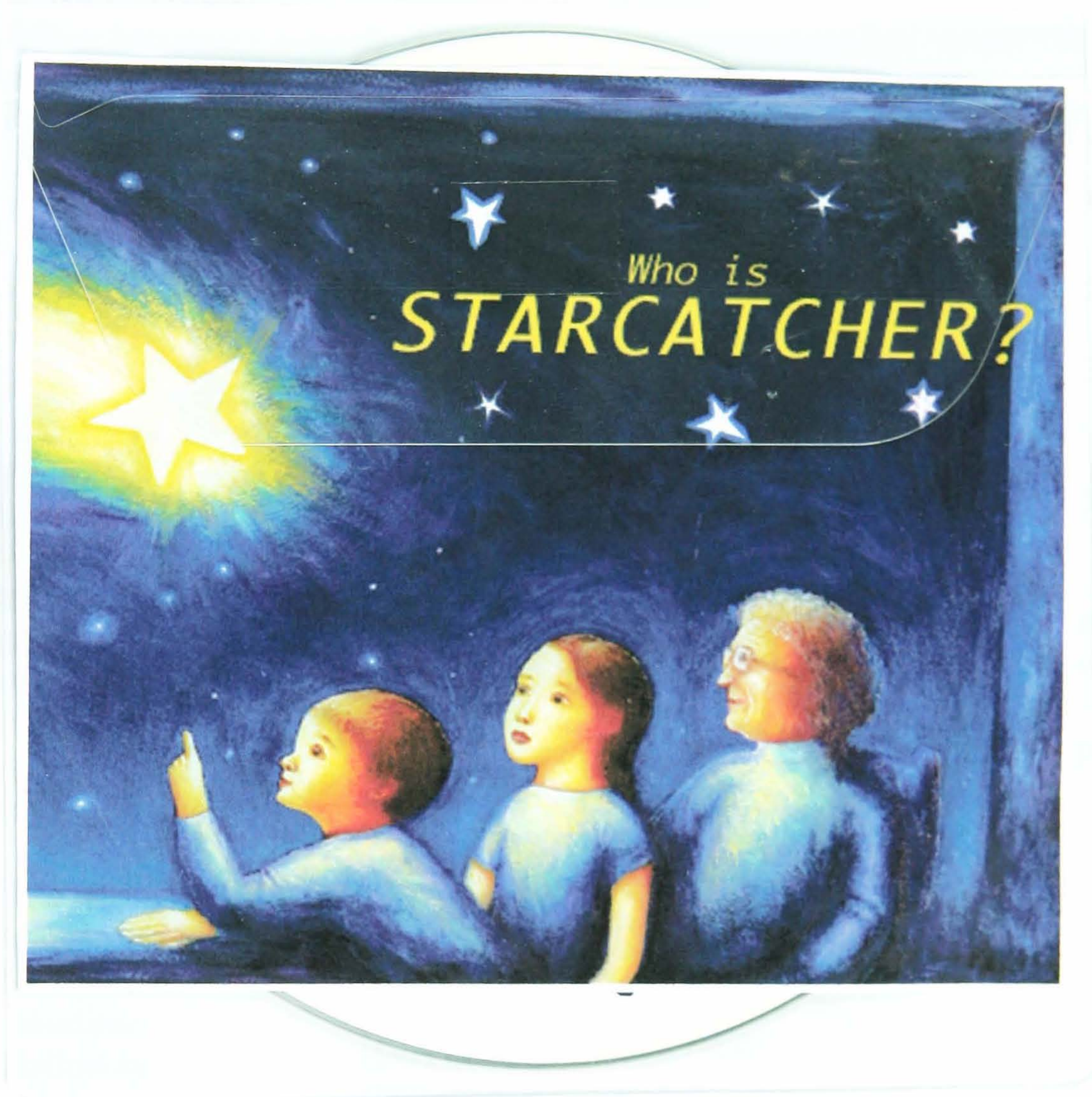
Work in progress, Multimedia Association December, 1995.

The Electronic Hearth: Interactivity and the Human Interface Paper, MediaWaves October, 1995.

What Makes Children Click? Presentation, Computer-Mediated Learning Group Middlesex University, December, 1994.

Appendix 4: Starcatcher Programme 1 of the Series (cassette tape and associated publications) See separate attachment.

Appendix 5: The CD-ROM of the research tool (Mac version)



Operating instructions

You should copy the whole folder RESEARCHTOOL onto you Hard Drive. The projector STARRY all other files should always be kept in the same folder.

1) Double click on STARRY
2) When the title screen appears hold down Alt + Apple keys
3) Click on top left star above 'Who is Starcatcher'
4) Choose Programme 1 (from the teacher's control panel)
5) Click Return to Main Menu
6) The Research Tool is now live. Rollover the figures to begin your exploration. If the mouse is not moved for a few second an audio file will play "Who is Starcather?"
7) Apple Q to exit

Other stars surrounding the 'Who is Starcatcher' title control other functions, but are for demonstration only. Use the Programme 1 option to switch on all facilities. You should have your sound functions on your Mac computer switched on to use the Research Tool (as all instructions are audio).

If you have problems please phone 0(44) 7778 537 505 or 0(44) 1992 597 292 Mike Howarth

Appendix 6: Field Work Diary Part 2: PowerPoint Presentations Reports For BBC Education Directorate

See in file Fieldworkdiary2.doc on accompanying CD-ROM

1 The NCET CD-ROMs in Primary Schools Initiative. Photographs and screen displays and analysis of classroom use of CD-ROMs during summer term 1994. "Schools needs." This material used by NCET Field Officers.

2 CD-ROMs in Secondary Schools . Photographs and reports signalling the growth in importance of CD-ROM in the school library, careers departments.

3 CD-ROM Task Cards . Evidence through working examples of National Curriculum applications of 10 well known Edutainment CD-ROMs (mainly from America).

4 Pros and Cons of NCET Project CD-ROMs . An analysis of classroom use of CD-ROMs, emphasising the problems created by their design.

5 CD-ROM DESIGN A: Iconitis. A focused examination, with examples, of the problems children experience due to poorly designed icons.

6 CD-ROM DESIGN B: Symbols and Metaphors . What makes children tick/click? An M.Phil introductory paper, - interface design, preconscious, children's metaphors.

7 Operating Conditions in Primary Schools (photos).

8 What's wrong with Dorling Kindersley CD ROMs in the classroom. Screen design and effect on children's perception.

9 The Perfect CD-ROM - a brief list of requirements.

10 The making of the Secondary Progs. CD-ROM Catalogue. The production sequence, facilities at Interactive Media OUPC and tools required with implications for future products for the Education Directorate.

10A Summary of PhD research at 1/12/95 Mike Howarth Interactive Media Group Open University Production Centre.

REPORT CIRCULATION LIST

1.	Jane Drabble	Director of Education
2.	Terry Marsh	Head of Programmes, BBC Education
3.	David Mortimer	Head of Multimedia Publications
4.	Clive Holloway	Head of Programmes, OUPC
5.	Liz Forgan	Controller Radio 4
6.	Heather Morris	Director Educational Publications
7.	Julie Cogill	Chief Education Officer
8.	Jay Johnston	Chief Assistant, Education Programmes
9.	Roger Fry	Resource Manager
10.	Sara Hemmings	Head of Developments, BBC Enterprises
11.	Geof Marshall-Taylor	Executive Producer Education Radio
12.	Jane Shaw	Chief Education Officer Continuing Education.
13.	Mathew Lee	Strategy Planner
14.	Lucia Jones	Head Education Policy and Services